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JAUFFRET, L.F.

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# THE WONDERS OF THE HUMAN BODY;

BEING

A FAMILIAR INTRODUCTION
TO A KNOWLEDGE OF ITS
*ANATOMY AND PHYSIOLOGY;*
FOR THE USE OF STUDENTS, AND YOUNG PERSONS
OF BOTH SEXES.

WITH SEVEN PLATES.

> I WILL PRAISE THEE, FOR I AM FEARFULLY AND WONDERFULLY MADE.
>
> PS. CXXXIX. 14.

*LONDON:*
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# ADVERTISEMENT.

THE following sheets are chiefly translated from a small French work, by **Jauffret**, whose interesting publications for youth are distinguished by their judicious adaptation to the capacities of his readers, and by the pleasing manner in which the instruction is conveyed.

To his performance have been annexed the Engravings, with their Explanations, and the Notes, selected principally from the works of esteemed and popular English Writers. These additions, as they tend to illustrate the subject, and introduce a variety of curious facts and observations, will not, it is presumed, be deemed an improper extension of the original plan.

The work will be advantageously read in conjunction with Mr. Walker's Grammar of Medical Science, and it forms a companion to works published under the title of the Wonders of the Telescope, Microscope, and Animated Nature.

*Bridge Street, March* 6, 1810.

# THE WONDERS OF THE HUMAN BODY.

## INTRODUCTION.

IN a fertile valley, inclosed by hills covered with wood, and watered by rivulets bordered with poplars, not far from Richmond, a small town remarkable for its delightful situation, stands a mansion, built with elegant simplicity, surrounded with a picturesque garden, a fine orchard, and a meadow extending to the banks of the Thames. In front of this house a fountain of white marble, overshadowed by weeping willows, runs all the year round, and contributes to produce a coolness equally agreeable and salubrious. The thirsty bees repair, humming, to drink in its basin. The birds, which are most familiar with man, throng hither in the middle of the day to seek a shelter from the heat: they sometimes flap the water with their expanded wings, as if to wash themselves in it, and then express their satisfaction in the most melodious strains. At a little distance from this mansion stands a farm-house which belongs to it. The flocks which, scattered during the day over the valley, enliven and embellish the landscape, are here assembled at night in capacious folds. Here the geese are incessantly cackling on the banks of a pond, or sporting on its surface; while hens, the patterns of maternal love, put themselves at the head of their newly-hatched broods, and relinquish to their young all the scattered grains which they have the good fortune to discover.

The name of this country-house well agrees with its situation: it is called Belle Place. Those who at a distance behold its slated roof, reflecting the rays of the sun, can scarcely refrain from envying the happiness of its inhabitants: and they who have once strolled through the winding alleys in its grounds, watered by running streams, and shaded by acacias, catalpas, and still rarer shrubs, can never forget so charming a spot.

Mr. Vermont, who resided in London, having, in his youth, chanced to visit the mansion and farm of Belle Place, the image of this delightful abode remained so deeply impressed upon his memory, that neither the turbulent pleasures of the metropolis nor the daily bustle of business could ever erase it. After an interval of fifteen years he still spoke of it to his wife and children with as much enthusiasm as if he had seen the place only the preceding day. If the latter praised the beauties of other country-houses, he would instantly exclaim: "Ah! what would you say if you had beheld Belle Place, its gardens, its orchards, and its charming meadows!" As he never mentioned this beautiful place without admiration, his children's curiosity was excited, and they one day begged their father to take them to see it. Their mamma, not less curious than Richard, Alfred, and Eliza, joined them in their endeavours to prevail upon Mr. Vermont to make an excursion to Richmond. Mr. Vermont, however, only replied with a smile: "It would be a still greater treat to me than to you, to see a place which I have always recollected with such pleasure: and it is with sincere regret that I am obliged by the pressure of business to defer our visit to a future time. I am grieved at this delay, but this you may rely upon, that I shall not lose sight of it."

From this time Mr. Vermont was more reserved towards his wife and children. Occupied entirely with business, he abstained from speaking in their presence of Belle Place; but he was secretly making preparations for a journey of which he was more anxiously desirous than any of his family, and which he wished to render as agreeable as possible.

One day, at the beginning of summer, Mr. Vermont came home in higher spirits than usual, and when his children ran to kiss him: "My dears," said he, "I bring you good news. I have just made such arrangements in regard to my business, that I shall henceforth be rather more at liberty. As there will be nothing to prevent my absence from London whenever I please, I shall no longer be debarred of the pleasure of taking little excursions with you into the country, which at this season of the year is so extremely beautiful. Indeed, I almost fancy that we are already rambling together in the woods, and on the banks of the rivulets: or that seated with your mamma on the verdant turf or on a stone bench covered with greyish moss, I am witnessing your infantine sports. Eliza soon runs away from you and comes to keep us company. Richard and Alfred run about a little longer, and then tired with their exercise, they also come and sit down beside me, and ask a thousand questions concerning every object that strikes them."

"O papa!" cried the children, "what pretty pictures you are drawing! But when shall we take one of the excursions which you are talking of?"—"To-morrow, my dears," replied Mr. Vermont: "every thing is ready and the coach is bespoken." On hearing this Richard and Alfred leaped for joy; while Eliza ran to her mamma to communicate the interesting intelligence and rejoice with her.

It is easy to imagine with what impatience the whole family awaited the morrow. For the first time, perhaps, Richard, Alfred, and Eliza, regretted within themselves the length of the night, and rose before the sun. The wished-for coach soon stopped at their door. They took their seats in it with a joy which it would be difficult to express, and left London just when the milk-women were entering the city with their burdens.

Notwithstanding the repeated questions

that were put to him, Mr. Vermont would not mention the place to which they were going. The coachman alone was in the secret, and before they had proceeded far from town, both the children and their mamma were total strangers to the road. They passed through villages, with the names of which they were unacquainted: but they received not the less pleasure from the prospect of the extensive plains, the enchanting hills, and the verdant meadows, that presented themselves by the way.

About ten in the morning the coach stopped for a moment at the entrance of a village, and then turned off into a cross road. "Papa," said Eliza, "if you are determined not to let us know the place to which we are going, tell us at least where we are. How many miles have we gone? What village is it that we are leaving to the right?"—"My dear," replied Mr. Vermont, "have patience a very little longer, and you will know all; we are not far now from our journey's end."

In about a quarter of an hour the coach stopped before an iron gate, through which was seen a house of handsome appearance. Along the wall, on each side of the gate, ran a row of lofty poplars, and in front appeared a capacious basin, from the middle of which rose a *jet d'eau* to the height of the first floor of the house. Mr. Vermont immediately alighted with his wife and children, with whom he advanced to the gate and rung the bell. After waiting a few moments: "There is nobody in the way I suppose," said he, "but we need not care about that. I have the key in my pocket, it was given me yesterday to make use of, in case the housekeeper should be absent, so that I can open all the doors for you."

Having unlocked the gate, he ordered the coachman to put his horses into the stable, and then, accompanied by his family, entered the mansion and began to inspect the apartments.

The reader may judge of the surprize of the children and their mamma, when, after having gone through the back rooms of the house, they were introduced into the apartments in front, the windows of which opened upon vast meadows, and commanded a view more extensive and picturesque than can possibly be imagined. "Oh!" exclaimed Eliza, "I see before the house a fountain of white marble, shaded by trees whose branches hang down to the ground. I see a large meadow intersected by small streams and bounded by a river; on the right is a garden, on the left an orchard, and in the back ground are hills covered with wood. I am sure that we are at Belle Place."—"I begin to suspect so too," said her mamma: "this place is truly delightful; 'tis only a pity that the housekeeper is not at home, as we might then have procured something or other for dinner, and afterwards have gone to look at the gardens and pleasure-grounds."—"We will go together to look at them," said Mr. Vermont, "and as to dinner, let us walk into the next room."

So saying, he opened a door and went with his family into an apartment, in the middle of which was a table laid for five persons. "What do I see?" cried Eliza. "Are these preparations for us? This table would be completely set out if there was something to eat?"—"Let's try," said Mr. Vermont, "if we can find the way into the cupboard which I see yonder." "It is open," cried Alfred, "and 'tis an enchanted cupboard, for it is full of nice things." Here in fact they found baskets of raspberries, gooseberries, and strawberries, some bottles of exquisite wine, and a pye of prodigious size. They sat down to table, and every one fell to with an excellent appetite. After dinner Mr. Vermont addressed his wife and children in the following terms: "What a delicious day is this for me! It crowns all the wishes which I have so long cherished in the recesses of my heart, and pays me with usury for the labor of fifteen years. In uniting my lot to that of a woman whom I loved, in acquiring the dear name of father, I never had any other ambition than to provide some day for my family a rural retreat, where, during the fairest season of the year, they might enjoy innocent pleasures. It is in the country that children learn to reflect, and that, from their more intimate association with nature, they accustom themselves to pry into her most remarkable phenomena. For this reason, I took such pains to increase my little fortune, and to get together the sum necessary for the purchase which I have made. This object I lately accomplished, and Belle Place is ours. It is a place which I dare say will please you, and of which you will always be fond. Come, let us take possession of it: let us go and look at the apartments which I have assigned you; let us visit the gardens and groves which surround the house." At these words his wife and children rose from their seats. They were too deeply affected to be able to make any reply: they could at first only throw themselves into his arms and weep for joy.

The rest of the day was spent in inspecting the rooms, all furnished with taste; in receiving the compliments of the farmer and gardener, who hastened to the house as soon as they heard of the arrival of its new owner; and lastly, in walking about the gardens and orchards, which were in excellent condition. Richard, Alfred, and Eliza, could scarcely believe the change which had taken place in their way of life. They slept soundly in their new habitation, and were quite surprized in the morning, on being awaked at sun-rise by the singing of the birds.

As soon as the children had become acquainted with their new residence, Mr. Vermont thus addressed them: "I have brought you hither, my dears, as much for your amusement as for your instruction. Free from other cares, I shall henceforward devote all my time to form your hearts, and to enlighten your understandings. I will direct all your studies. We will daily take a walk together, which will furnish us with matter for useful observations. You will ask me questions, which I shall endeavour to answer, and your morning's task shall be to commit to writing, the conversation of the preceding day."

The children were highly delighted with this plan. They all promised to comply with the wishes of their father, and it was agreed that their walks should begin the very next day.

## FIRST CONVERSATION.

### OF THE HUMAN BODY IN GENERAL.

Richard, Alfred, and Eliza, did not fail on the morrow, to remind Mr. Vermont of his promise, to take them out a walking. The weather was fine. The heat was moderated by a breeze which gently ruffled the moveable foliage of the poplars, and produced slight undulations in the thick grass in the meadows. Mr. Vermont was not less eager to fulfil his promise than they were to demand its accomplishment. He quitted the house with his children, and they proceeded to the end of the valley, which lay below it. By the way, Eliza, curious to know what would be the subject of this day's conversation, fondly took her father's hand and said: "What are you going to converse with us about to-day, papa? Is it not about butterflies? You smile, have I guessed right?"

*Alfred.* Papa promised me that, when we were in the country, he would tell me some day about the different kinds of birds.

*Richard.* And he promised to teach me to distinguish plants.

*Mr. Vermont.* I intend, my dears, to keep all these promises; but I think it is of importance, before I treat of plants, birds, or butterflies, to make you familiar with things which much more nearly concern us, and which authors have hitherto but too much neglected to reduce to the capacity of children. I shall, therefore, speak to you—

*Eliza (eagerly).* About what, papa?

*Mr. Vermont.* About a machine composed of an infinite number of parts of different natures, solid, soft, fluid, spirituous, all enclosed in one common case: of a machine both elegant and majestic, which rises perpendicularly on two pedestals, one on the right, the other on the left, surmounted by two oblique columns, which support an edifice of three stories, communicating with each other by apertures formed with great art in the floors that separate them: of a living and walking machine, containing within itself the principle of its motion and preservation, not only for a few years, but sometimes for more than a century.

*Richard.* Papa, I can guess without much trouble, that this machine is the Human Body.

*Mr. Vermont.* It is, my dear. Have you ever reflected on the admirable proportion of the parts of which it is composed?

*Richard.* No, never.

*Mr. Vermont.* Let us sit down here upon the turf, and begin to reflect a little on the subject; or rather let us first ascend that verdant hillock. Let us look round on every side, and enjoy the magnificent spectacle exhibited to our view. Nothing, my dears, is a stronger evidence of the dignity of man, and of his pre-eminence over the different species of brutes, than the erect position of his body, and the majesty imprinted upon his countenance. Some ignorant reasoners have asserted, that this upright posture is not natural to us; but the conformation of the head and of the foot, as well as of several other parts of the human body, clearly prove that those who thus argue, are wrong. Other animals have their eyes placed on each side of the head, so that they can see the horizon; but man, were it not for his erect position, would fare far worse in respect to sight than any of the brute creation. His eyes would be turned directly towards the ground; and he would not be able to shun a thousand dangers which other animals avoid by flight, when their sight apprises them of their approach. If, therefore, any thing evinces that nature destined man to walk with his head erect, it is the very conformation of his head. In his upright attitude, he takes in at one view the heavens and the earth. He can look upwards, downwards, and all around him; and so far from having occasion to envy the posture of the creatures about him, he may justly consider his own as a favour conferred upon him by nature*.

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* Dr. Paley has availed himself of a striking contrivance in the structure of large quadrupeds, to demonstrate the position which those animals and man were respectively intended to assume.—"About each side of the neck of large quadrupeds," says he, "runs a stiff, robust cartilage, which butchers call the pax-wax. It is a tough, strong tendinous substance, braced from the head to the middle of the back: its office is to assist in supporting the weight of the head. It is a mechanical provision, of which this is the undisputed use; and it is sufficient, and not more than sufficient, for the purpose which it has to execute. The head of an ox or a horse is a heavy weight, acting at the end of a long lever, (consequently with a great purchase) and in a direction nearly perpendicular to the joints of the supporting neck. From such a force, so advantageously applied, the bones of the neck would be in constant danger of dislocation, if they were not fortified by this strong tape. No such organ is found in the human subject, because, from the erect position of the head, (the pressure of it acting nearly in the direction of the spine) the junction of the vertebræ appears to be sufficiently secure without it. This cautionary expedient, therefore, is limited to quadrupeds: the care of the Creator is seen where it is wanted."

*Eliza.* Papa, I am sorry to interrupt you, but do you see the beautiful effect of the sun's rays through those trees? What a number of diamonds glitter among the foliage. It has almost the appearance of fire-works.

*Mr. Vermont.* It is indeed a most brilliant spectacle. Let us walk to the grove; we shall enjoy it in still greater perfection.

*Alfred.* But, papa, we are forgetting the principal subject of our conversation.

*Mr. Vermont.* Oh, no! While we are looking at the trees, we may make this interesting remark, that nature has been so highly favourable to man, as to proportion all the objects around him to the dimensions of the human body. Do you observe, my dears, the structure of these trees, and the form of the trunk which supports their branches?

*All the children together.* Yes, papa.

*Mr. Vermont.* This trunk resembles a column.

*Eliza.* Very nearly.

*Mr. Vermont.* Or rather, the column is

but an imitation of it. Be that, however, as it will, the trunks of the trees rise to a certain height, and support the largest branches, from which the smaller boughs shoot forth and cross each other in every direction.

*Alfred.* They do indeed.

*Mr. Vermont.* But is it then, without design that the trunk rises in this manner, to a certain height? Is not this height exactly proportioned to the human stature? Why have trees an upright stem before they begin to shoot out into branches? Could they not begin to throw them out close to the ground?

*Richard.* Indeed I can't see why they might not.

*Mr. Vermont.* But then man would not be able to walk in the shade of the trees; the woods, the orchards would oppose impenetrable barriers: whereas, in the present state of things, nothing hinders him from walking wherever he pleases; the most extensive forests forming, as it were, temples of verdure, the trunks of the trees serving for columns, while the branches covered with foliage compose the roof*.

*Richard.* I never before remarked this striking proportion which exists between all the objects of nature and the human body.

*Mr. Vermont.* I have mentioned only one example; but if you take notice of the form of the fruits, and in general, of that of all the objects which surround us, you cannot help observing that our body has the most suitable figure and dimensions which could possibly have been given to it, relatively to those objects. A much larger or a much smaller size would have been extremely embarrassing and inconvenient, not only to the individual, but also in regard to his occupations, and to society. With the stature of a dwarf, man would have been exposed to a thousand dangers; with the dimensions of a giant, he could not have been conveniently supplied with food: the largest and most juicy animals would not have furnished sufficient food for his subsistence; and had the beasts been made larger in proportion, the earth would not have produced grass enough to feed them*.

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* "As to trees," observes the eloquent St. Pierre, "though they are replenished with a vegetative force which raises them to a great height, yet few of them send out their first branches except at some distance from the ground: so that though they form at a certain elevation, an intertexture impenetrable to the sun, extending to a considerable distance around them, they, however, leave about their bases avenues sufficient to render them accessible, and to enable man to traverse the forest with ease in every direction.—Such then are the general dispositions of vegetables on the earth with relation to the necessity which man has to range over it: the herbage serves as a carpet to his feet, the shrubs as a ladder to his hands, and the trees as parasols over his head."

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* "We are told," says St. Pierre in his *Studies of Nature*, "that real giants formerly existed: but this truth, like all those of which nature no longer furnishes any evidence, is to us inconceivable. If Polyphemes, lofty as a tower, ever existed, they must have sunk most soils beneath them as they walked. How could their long and clumsy fingers have milked the little goats, reaped the corn, mowed the grass, and gathered the fruits of the orchard? Most of our aliments would have escaped their eyes as well as their hands.—If, on

*Alfred.* That is perfectly clear.

*Mr. Vermont.* Now, my dears, if the erect posture is the most suitable to man;

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the other hand, there had ever been generations of pigmies, how could they have levelled the forests to cultivate the earth? They would have lost themselves among the grass. Every rill would have been to them a river, and every pebble a rock. The birds of prey would have carried them off in their talons, unless they had made war upon their eggs, as Homer's pigmies did upon the cranes."

Not only the ideas, but the very words of this author have been borrowed by a late popular English writer. "A giant or a pigmy," says he, "could not have milked goats, reaped corn, or mowed grass; we may add, could not have rode a horse, trained a vine, shorn a sheep with the same bodily ease as we do, if at all. A pigmy would have been lost among rushes, or carried off by birds of prey."—*Paley's Natural Theology*, p. 320.

Dr. Gregory, treating of the same subject in his *Economy of Nature*, observes: "If the size of man was much greater than it is, supposing his strength to be only in proportion, his motions would be much slower and more laborious; nor would his increase of size be entirely compensated by a diminution in the force of gravitation, for this would expose him to inconveniencies on account of the various relations in which he stands to other objects. On the contrary, was man much smaller, if the dimensions of his body are admirably proportioned to every thing about him, the harmony of the parts which concur to move this body, and to keep it in equilibrium, is not less striking. What art do we not discover in the formation and arrangement of the bones, from the head to the feet! The vertebræ of the neck and of the spine are short, flat, and strongly bound together by cartilages and ligaments of a particular nature. If the vertebral column had been of one single piece, could it have adapted itself with such facility to the motions of the body, and have supported its weight and that which is occasionally added to it? Should we stand so firmly

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though he would gain in celerity what he would lose in force, yet his weakness would incapacitate him for acting with advantage on considerable masses of matter. On the whole, it should seem, that neither an increase of size with an increase of gravitation, nor a diminution of size with a diminution of gravitation, nor an increase of either with a diminution of the other, would in general so well suit the conveniencies of man, and his relation to other beings, as the state in which he at present subsists."

upon our feet, were there not underneath the foot itself, a hollow which the nerves, veins and arteries defend in walking or standing, from compression? What is the object of the perfect symmetry, and the wise disposition of all the parts of the human body, unless to keep it in equilibrium, when standing or moving? The shoulders, the arms, the sides, are exactly counterbalanced on the one hand; on the other, the internal parts of the chest and belly are in equipoise with the shoulders, the back, and the posterior parts; and as to the prodigious number of muscles distributed with exquisite art over the whole body, what can be more astonishing than to see them accommodate themselves with such promptitude to its different postures and to all its motions, without ever violating the strictest laws of equilibrium?

*Richard.* I run and jump very often, but till now, I never once thought of the muscles that must be set in motion by those exercises.

*Mr. Fermont.* Just as many people

make use of their eyes, without ever having the curiosity to study their structure.

*Eliza.* Papa, will you give us a description of it presently?

*Mr. Vermont.* Yes, my dear; if you and your brothers like to hear me, I will give you successively some familiar notions respecting sight, hearing, smell, taste, feeling; the bones, and particularly those of the head, hand and foot; the muscles, the arteries and the veins; in short, respecting every thing of which the human body is composed. But this is enough for the present: let us go. Reflect from time to time on what you have heard, and be sure to commit it to writing, in order to impress it more deeply on your memory.

## SECOND CONVERSATION.

### OF THE EYES.

Mr. Vermont, fearful of abating the attention of his children by terms too scientific, and images too repulsive, determined not yet to exhibit to them the human body divested of those external coverings, with which nature has wisely enveloped its internal parts, not only to preserve them from accidents, but also to conceal from the view their action and their structure. He thought it more adviseable to call forth their admiration of whatever is remarkable in the exterior of the body. The next time he was seated with his children on the brow of the wood-crowned hill at the farther end of the valley, he communicated to them his intention. "When we behold the fore-part of the head, or the human face," said he, "nothing appears so striking as the eyes. It is fit, therefore, that we should commence our examination of the human body, with the consideration of those precious orbs which increase a hundred-fold the beauty of the countenance, and afford us the enjoyment both of the spectacle of 'the human face divine,' and of the magnificence displayed in the universe*."

While Mr. Vermont was thus speaking, Richard, Alfred and Eliza looked at him with the utmost attention, and Alfred observed in his eyes a phenomenon, which he had never before observed. "Oh, papa," cried he, all of a sudden, "look at me. If you did but know—I see in your eyes"—

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* "As long," observes Sturm, "as the soul remains perfectly tranquil, all the features of the face are in a state of repose; but when the mind is agitated, the countenance becomes an animated picture, in which the passions are delineated with equal delicacy and force. Every affection of the soul has its peculiar expression, and every alteration of the features is a characteristic sign of the most secret emotions of the heart. The eye in particular expresses these passions so distinctly, that it is impossible to mistake them: it is in a superior degree to any of the other organs of the senses, an immediate interpreter of the soul, by means of which the wildest passions and the softest emotions are expressed with the greatest truth and energy. Hence it may with propriety be called the mirror of the soul and the organ of the understanding."

*Mr. Vermont.* What do you mean? What is it you see in my eyes?

*Alfred.* I see all the fields in miniature, as in a looking-glass.

*Mr. Vermont.* All the fields!

*Alfred.* Yes, papa; I see the sky in them, and the trees, and the river——and I see myself too. Oh! how small I am. My face is no larger in your eyes than a pin's head——but yet I can distinguish that it is myself*.—And do you see yourself too in my eyes?

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* "In considering vision as achieved by the means of an image formed at the bottom of the eye, we can never reflect without wonder upon the smallness, yet correctness of the picture, the subtility of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects which it contains are all preserved; are all discriminated in their magnitudes,

*Mr. Vermont.* Yes, perfectly well.

*Eliza.* And so do I.

*Richard.* And I see myself at one and the same time, in Alfred's eyes, in Eliza's, and in papa's.

*Alfred.* And do you see the fields in them too?

*Richard.* Yes, to be sure.

*Alfred.* What papa, is the eye then made like a looking-glass?

*Mr. Vermont.* Yes, but with this difference, that it is not flat like a common

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positions, figures, colours. The prospect from Hampstead Hill is compressed into the compass of a sixpence, yet circumstantially represented. A stage-coach travelling at its ordinary speed for half an hour, passes in the eye, only over one-twelfth of an inch, yet is this change of place in the image distinctly perceived throughout its whole progress: for it is only by means of that perception that the motion of the coach itself is made sensible to the eye. If any thing can abate our admiration of the smallness of the visual tablet compared with the extent of vision, it is a reflection, which the view of nature leads us every hour to make, viz. that in the hand of the Creator great and little are nothing."—*Paley's Natural Theology,* p. 35.

looking-glass. Its figure is nearly round like a ball.

*Richard.* And if it were flat, what then?

*Mr. Vermont.* In that case, it could not receive perpendicularly the image of a larger space than it occupies itself. I shewed you, at dinner, on the convex part of a bottle that was brought to table, a representation of all the country round us.

*Richard.* You did. And every object was there represented in miniature with surprising accuracy. I saw upon the bottle, the whole valley with its clumps of trees, the blue sky interspersed with white clouds, and I could even distinguish the trembling of the leaves.

*Mr. Vermont.* The reason of this is evident. The glass being convex, collects a greater number of perpendicular rays than one which is not. You will some time be better able to understand this explanation. For the present this experiment is sufficient, and you may repeat it as often as you please. But with respect to the eye, if its spherical and bulbous figure is adapted to the collection of the rays, it is likewise most favourable to its motions. In order to see objects, it is necessary that the eye should turn towards those objects, and consequently, that it should be capable of moving to every side. The eye then, by this figure, is perfectly fitted for every motion; so that it can turn with great facility to whatever side it pleases, according as occasion may require.

*Richard.* How does it happen, papa, that my eyes move so quickly in the different directions which I choose to give them? How do they move at all? What springs cause them thus to roll whichever way I please?

*Mr. Vermont.* My dear, the utility of the motions of the eye is evident. In order to spare us the trouble of turning our heads continually towards the objects which we want to look at, nature has placed in the orbit of the eyes six muscles which are at our command, and are admirably contrived to move them in every direction, upward or downward, to the right or to the left, or to whatever side occasion requires. If we want to look upward, the superior muscle lifts up the orb of the eye, for which reason it is called the *levator*. If we would cast our eyes down to the ground, the lower muscle pulls them down, and hence it has the name of *depressor*. There is a third muscle, termed *abductor*, which moves the globe outwards; a fourth, which draws the eye toward the nose, is called the *adductor*. These four are denominated *straight* muscles. The two remaining ones are called *oblique*, and their use is to keep the eye steady in all its movements, and to counterbalance the action of the other muscles. The structure of one of these oblique muscles is very remarkable, and truly worthy of admiration. It passes through a cartilaginous ring, just like a cord over a pulley; and being attached at two points to the globe of the eye, it assists in keeping it firmly and steadily fixed on any object. This curious mechanism of the muscles not only prevents frightful contortions and unsteady motions of the eye, but likewise enables this natural telescope to advance, to recede, in a word, to move in every direction, so that one single eye, from the prodigious variety of situations which it is capable of assuming, performs the service of ten thousand.

*Richard.* But papa, how comes it that objects are painted in the eye? What is the eye composed of?

*Mr. Vermont.* At the anterior part of the eye you observe a projecting circular portion, which, from its substance being transparent, like horn, is called the *cornea.* (See *pl.* 1. *fig.* 2.) It is of a convex figure, and resembles the glass of my watch. The ball of the eye is a case of a globular form, being filled with three humors, the *vitreous,* the *crystalline,* and the *aqueous.* The iris floats in the aqueous humor, and divides it into two parts, which communicate with each other, through the aperture in the middle of the eye called the pupil. The rays of light penetrate the transparent cornea, by whose convexity they are united into a focus, passing through the aqueous humor and pupil of the eye into the crystalline humour, which makes them converge still more; and after this concentration, they penetrate the vitreous humor, and imprint the image of external objects on the retina, which is an expansion of the optic nerve, and conveys those images to the mind. But to give you a better idea of what takes place within the eye when it is struck by any object, I shall to-morrow morning make an experiment at home, which you may afterwards easily repeat yourselves. We will close the window-shutters, and adjust to a hole that must look towards the fields, a pasteboard tube, a foot long, and four or five inches in diameter, provided, at the end next the window, with a convex glass, having a focus of six inches; that is, collecting the rays of light at the distance of six inches; and the edge of which we shall cover with a narrow circle of pasteboard, to prevent too much light from entering. Into this tube we will slide a second, covered with a piece of fine parchment, or bladder, at the end which enters the first tube. We will direct this kind of telescope to the fountain upon the terrace. You shall put your eyes to the tube to see what is passing within it, and you will perceive the obelisk and its pedestal represented in miniature upon the parchment, in the most distinct manner, but in a reversed position; you will likewise see, in the same way, the weeping willows which overshadow the fountain. Now this artificial machine is a rude, but very faithful image, of what takes place in our eyes; the order and the operation are the same. The little circle of pasteboard, placed round about the convex glass, to throw off the rays, which by their multitude would confuse or weaken the image, answers to the iris, or coloured circle in the anterior part of the eye, with this difference, that the pasteboard circle always presents the same aperture to the rays; whereas the iris of the eye, by means of its small muscles, enlarges the aperture which we term the pupil, when we have occasion for a stronger light, and instantly contracts it when a too vivid light would render the image confused, or injure the organ*.

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* It is owing to this contractile power of the iris, that when a strong light suddenly succeeds to darkness we are under the necessity of closing the eye-lids, or of turning away the head till the pupil has been accommodated to the change.

"It is to be observed," says Paley, "that, in the human subject, this hole in the eye, which we call the pupil, under all its different dimensions retains its exact circular shape. This is a structure extremely artificial. Let an artist only strive to execute the same. He will find that his thread and strings must be disposed with great consideration and contrivance to make a circle, which shall continually change its diameter, yet preserve its form. This is done in the eye by an application of fibres, *i. e.* strings, similar in their position and action to what an artist would and must employ if he had the same piece of workmanship to perform."

Another remarkable property possessed by the eye ought not to pass unnoticed, that is, the power of adapting itself to the perception of objects that lie near at hand, as well as of those which are placed at a considerable distance. According to the principles of optics, rays issuing from points placed at a small distance from the eye, and which must consequently enter it in a spreading or diverging order, cannot by the same instrument in the same state be made to form an image in the

*Richard.* What, papa, is the little aperture, called the pupil, capable of enlarging and contracting according to circumstances?

same place, with rays proceeding from objects situated at a much greater distance, and which rays arrive at the eye in nearly parallel directions. It was therefore necessary that the organ should undergo an alteration, and receive an adjustment corresponding with the exigency of the case. From some recent discoveries, it is found that by the action of the straight muscles, whenever the eye is directed from a distant to a near object, three changes are produced in it at the same time, all severally contributing to the adjustment required. The cornea, which is elastic and capable of being elongated one eleventh of its diameter, and of contracting spontaneously to its former dimensions, is rendered more round and prominent; the crystalline lens underneath is pushed forward, and the axis of vision, as the depth of the eye is called, is elongated. "These changes in the eye," observes Dr. Paley, "vary its power over the rays of light in such a manner and degree, as to produce exactly the effect which is wanted, viz. the formation of an image upon the retina, whether the rays come to the eye in a state of divergency, which is the case when the object is near to the eye, or parallel to one another, which is the case when the object is placed at a distance."

*Mr. Vermont.* Yes, my dear; and to ascertain this, you need only go out of a dark place into open day-light, and out of a light place into the dark with a looking-glass in your hand. You will distinctly see the pupil enlarge as you move into the dark, and contract again when you go into the light. The manner in which the rays are refracted in the convex glass, and paint the reversed image of the object upon the parchment, is an exact imitation of the refraction of the rays in the humors of the eye. The crystalline, as I have observed, has the form and transparency of a real lens or convex glass. The retina, which is placed behind the crystalline humor, is like the parchment upon which objects are painted in a reversed position, after having undergone several successive refractions in the humors. (See *pl.* 1. *fig.* 4.)

*Richard.* But, papa, are objects really painted on the back part of the eye in an inverted position? I should think that in this case we must see them so too; but fortunately we do not.

*Mr. Vermont.* Some of the most eminent physiologists, especially Buffon and Le Cat, have asserted that this is the case with respect to infants, some days after their birth, when they begin to distinguish objects. Those writers maintain that, at this period, a child sees objects in an inverted position; but that by touching them with his hands, he gradually makes himself acquainted with their real situation; and that by the sense of feeling, he thus rectifies this error of the sense of sight. This opinion, however, has not at present many supporters. It is generally conceived, that notwithstanding the inverted position of objects in the eye, we naturally see them in their real position. Writers on natural philosophy explain this in a very satisfactory manner, and we shall again recur to this subject on some future occasion, when our conversations shall relate to that science. Let us meanwhile be content to admire this phenomenon.

*Richard.* Indeed, it is truly admirable.

*Mr. Vermont.* Another, not less so, is, that though the image of an object is painted in both eyes, we nevertheless cannot see it double.

Vandermonde conjectured that children, when they begin to distinguish objects, for some time see them double. This is evidently a mistake; for as the sounds which reach both our ears at once are not transmitted double, so objects painted in both eyes at once do not transmit two images.

*Richard.* I think I have heard mamma say, that when we were very little, we could not see distinctly; and that we were several months before we distinguished persons, and the figure of objects.

*Mr. Vermont.* That is not surprizing; it is a circumstance which I can explain to you in a very intelligible manner. I have a German book in my pocket. Take it, and read in it if you can.

*Richard.* What a book, papa! How strangely it is printed! Who could decypher such characters as those!

*Mr. Vermont.* These pages, which to

me are so interesting, appear to you, I suppose, like a shapeless mass of letters, huddled together in the greatest confusion.

*Richard.* Yes, they do.

*Mr. Vermont.* Well, my dear, before you learned to read, English was German to you. If you should learn the latter language, the confusion which you now see in this book would gradually disappear; every word would appear distinct, and would at last become perfectly intelligible to you. Now, at our birth, Nature resembles a book which we have not yet learned to read; at first, it exhibits nothing to our view but the utmost confusion; the various objects are jumbled together; and we are incapable of distinguishing such as are very near, from those which are at a great distance. It is only by studying them one after another, by touching and examining them, that we learn to judge of their form and distance. The eye then follows with docility the instructions of the hand, and becomes habituated to see in a correct manner.

*Alfred.* Why have we two eyes, papa? Why are they placed in the head? Why——

*Mr. Vermont.* These are questions, my dear, which you might answer yourself. The eye, like a sentinel, is stationed at the highest place of the body. Its situation, as you see, is as suitable as its form. It is necessary that the eye should move in order to see objects; and it is equally needful that a prompt communication should exist between it and the brain. It has, therefore, been placed in the head, and that not without some design; for the head is formed in such a manner as to be capable of turning and moving on either side, according to circumstances, and in compliance with our will.

*Eliza.* I should think, papa, that if our eyes were placed in our hands, we could raise them higher than our heads; we might turn them on every side, and be able to see farther.

*Mr. Vermont.* Yes, my dear; but in the hand they would have been exposed to a thousand dangers, and the hand itself would have been rendered less active and less useful.

*Eliza.* It is very true.

*Mr. Vermont.* Another circumstance worthy of remark, is the manner in which the eye is placed in the head, namely, in front or on the side, according to the particular condition of each animal. In man, and in some animals which see little more than what is before them, the eye is situated in the front of the head, but disposed in such a manner that it is capable of receiving the impressions of nearly the whole hemisphere of objects, which lies before it from right to left. In birds, and in some other creatures, the eyes are so placed, as to see nearly all round them; by which arrangement those animals are the better enabled to seek their food, and to avoid the dangers to which they are exposed In others, the eye is situated in such a manner, that they see better what is behind and on either side of them, which renders them capable of perceiving their enemy, and escaping from him when pursued. Thus in the hare and rabbit, the eyes are very convex and prominent, so that they can see nearly quite round them; whereas in the dogs which pursue these animals, those organs are placed more in the front of the head, to look rather before than behind them*.

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* This adaptation of the eyes of animals to their respective wants, is observed not only in regard to the position, but also with reference to the constitution of those organs.

On this subject Dr. Monro, in his *Comparative Anatomy,* makes the following interesting remarks:

"All quadrupeds have at the internal canthus of the eye, a firm, strong membrane, with a cartilaginous edge, which may be made to cover some part of their eye, and this is greater or less in different animals, as their eyes are more or less exposed to dangers in searching after their food. This *membrana nictitans,* as it is called, is, however, not very large in all these animals. Cows and horses have it so large as to cover one half of the eye-lid like a curtain, and at the same time it is transparent enough to allow abundance of the rays of light to pass through it. Fishes have a cuticle always over

*Alfred.* Are there any animals, papa, that have but one eye?

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their eyes, as they are ever in danger in that inconstant element, the water. In this therefore we may observe a sort of gradation.

"All quadrupeds have a seventh muscle, called suspensorius. It surrounds almost the whole optic nerve, and its use is to sustain the weight of the globe of the eye, and to prevent the optic nerve from being too much stretched, without obliging the four strait muscles to be in a continual contraction, which would be inconvenient: at the same time this muscle may be brought to assist any of the other four, by causing one particular portion of it to act at a time.

"The next thing to be remarked is the figure of the pupil, which is different in different animals, but always exactly adapted to the creature's way of life, as well as to the different species of objects that are viewed. Man has it circular, for obvious reasons; an ox has it oval, with the longest diameter placed transversely, to take in a larger view of its food: cats again have theirs likewise oval, but the longest diameter placed perpendicularly; they can either exclude a bright light altogether, or admit only as much as is necessary. The pupil of different animals varies in wideness, according as the internal organs of vision are more or less acute. Thus cats and owls, who seek their prey in the night, or in dark places (and consequently must have eyes so formed

*Mr. Vermont.* Your question, my dear, leads me to an important observation, re-

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that a few rays of light may make a lively impression on the retina) have their pupils in the day time contracted into a very narrow space, as a great number of rays would oppress their nice organs; while in the night, or where the light is faint, they open the pupil and very fully admit the rays.

" The posterior part of the choroid coat, which is called the *tapetum,* is of different colours in different creatures. Oxen, feeding mostly on grass, have this membrane of a green color, that it may reflect upon the retina all the rays of light which come from the objects of that color, while other rays are absorbed: thus the animal sees its food better than it does other objects. Cats and owls have their tapetum of a whitish color; and for the same reasons have their pupil very dilatable and their organs of vision acute: and we shall find that all animals see more or less distinctly in the dark, according as their tapetum approaches nearer to a white or black color. Thus dogs, who have it of a greyish color, distinguish objects in the night better than man, whose tapetum is dark brown, and who, I believe, sees worst in the dark of any creature; it being originally designed that he should rest from all kinds of employment in the night-time. The difference then of the color of the tapetum, as indeed the fabric of any other part in different creatures, always depends on lative to the number of the eyes. They are never fewer than two; at least, I do not know that any animals have ever been seen with less than that number. In some they are more numerous*.

*Alfred.* But papa, why should we have two eyes? Is it only for the sake of symmetry?

*Mr. Vermont.* Is it possible that you cannot perceive the admirable wisdom of Providence in this arrangement? Don't you see that this number is perfectly adapted to embrace a larger angle or a more extensive field of view? Are you not aware that, by this provision, man and animals are in some measure prepared

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some particular advantage accruing to the animal in its particular manner of life from this singularity."

* "The greatest part of insects have more than two eyes. The spider and scorpion have eight. Some insects have more than a thousand eyes collected in two orbits. In a fly sixteen thousand eyes have been counted; in a beetle six thousand three hundred and sixty-two; and in a butterfly sixty-four thousand six hundred and fifty." *(Sturm's Reflections).*

for the loss of one of these two organs, which are so beautiful and so necessary?

*Richard.* I held my eyes before in great estimation, but must confess, that till now, I never was fully acquainted with their value.

*Mr. Vermont.* To form a correct judgment of that, it is sufficient to consider the extreme precautions which have been taken by Nature for the purpose of defending them against all dangers. Like a diamond of inestimable value, the eye is lodged in a strong box, constructed with great art. The eye itself is protected in front by a covering of exquisite workmanship. The eye-lids, the covering to which I allude, have a soft smooth surface, that they may not injure these delicate organs. Whether the fear of any accident obliges us to shut them, or we chuse to open them, the eye-lids are so admirably adapted to either of these motions as to perform them in an instant. They are kept moist by a fluid which the lacrymal gland, situated above the eye, near the external angle, is continually pouring between the eye and the eye-lids, to facilitate their movements*. They are fortified, if I may so express myself, with a palisade of eye-lashes, which serve to repel whatever would attack the eyes when they are open, and to envelope them, that they may repose unmolested, when they are closed and rendered useless by sleep. They have, moreover, the advantage of being hidden and defended by eminences; for on the one hand they have the protuberance upon which the eye-brows are situated, to stop the sweat which runs down from the forehead; and on the other, the cheeks project a little to preserve them from accidents from below.—But let us make an experiment. Come near me. *(He strikes the palms of his hands together with violence).*

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* The contrivance for carrying off the superfluous part of this briny wash is truly admirable. "It is conveyed to the nose," says Paley, "through a perforation in the bone as large as a goose-quill. When once the fluid has entered the nose, it spreads itself upon the inside of the nostril, and is evaporated by the current of warm air, which, in the course of respiration, is continually passing over it. Can any pipe or outlet, for carrying off the waste liquor from a dye-house, or a distillery, be more mechanical than this is? It is easily perceived that the eye must want moisture; but could the want of the eye generate the gland which produces the tear, or bore the hole by which it is discharged—a hole through a bone?"

*Alfred.* What's that for, papa? Why did you clap your hands together with such force?

*Mr. Vermont.* You were all afraid; you all suddenly shut your eyes.

*Alfred.* Did I shut my eyes? I did not perceive it.

*Mr. Vermont.* The reason is, because that movement is performed with extreme celerity, and without any participation of your will. It is a movement of Nature, which immediately closes the eyes when they are threatened with the least danger: so sure is the providence of instinct, and so great is the flexibility of the eye-lids!

*Eliza.* I never supposed that my eyelids were so attentive to defend my eyes.

*Mr. Vermont.* They have another use besides.

*Eliza.* And what is that, papa? I am curious to know.

*Mr. Vermont.* As they consist of a thin and flexible, but yet strong skin, they not only serve to defend the eye, but are likewise adapted to keep its surface clean. Their edges are fortified by a soft and tender cartilage; by means of which they not only perform their functions the better, but open and shut with greater ease. From this cartilage rises the palisade of hairs which I have already mentioned, of such great use to defend the eye from too vivid a light. The eye-lashes are of the same nature as the hair of the head. Why, then, do they not grow, like the hair, to an inconvenient length? Why is it that when they have attained the length of perhaps half an inch, they suddenly stop and grow no more? Why do the lashes of the upper lid rise upward, bending in the form of a small bow? Why do the lower ones take a contrary direction, and likewise form a small bow, but with its back to the upper? Is it not evidently for our advantage that Nature stops their growth, and gives them so convenient a direction?

*Alfred.* O papa! as I look at your eyes and eye-lashes, I see that what you say is true.

*Mr. Vermont.* I might tell you many other particulars relative to the structure of the eyes. I have said nothing to you concerning either the ramifications of the nerves in the globe of the eye, or of the arteries, or of the veins which are many of them imperceptible, and run through every part, or of the utility of the black color of the choroid*; but what I have told you will be sufficient to give you some notion of an organ, without which we should be plunged into profound darkness, and every moment exposed to a thousand dangers. To impress on Eliza's mind the remembrance of our conversation, I shall endeavour to speak to her for a moment in the language of signs, which is often the most expressive. *(He covers her eyes with both his hands).*

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* The ball of the eye is a case of a globular form, consisting of three coats; the external one called the sclerotica; the choroid, the intermediate one abounding with blood-vessels, and the internal coat, formed by the retina. Respecting the different colors of the choroid in different animals, see note, p. 47.

*Eliza.* Why do you cover my eyes, papa?

*Mr. Vermont.* That you may be sensible how unfortunate you would be, if you were deprived of sight; that you may pity your wretched fellow-creatures, who are in that condition; that you may every day thank your Creator, for having given you an organ, by means of which you enjoy the light of heaven, and which serves to direct your steps. Nature is at this moment decked with all her splendor; the azure sky and verdant earth exhibit a matchless spectacle. But this spectacle is lost to you. Darkness thicker than that of night surrounds you on every side. But be of good cheer, Eliza, and be thankful to Providence; for this darkness

Section of the Human Eye

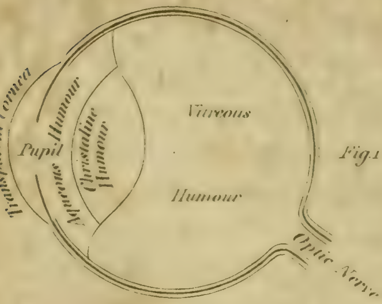


Fig.1

Human Eye

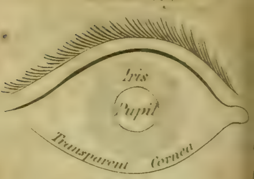


Fig.2

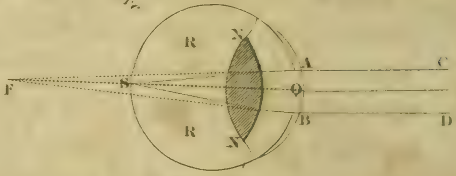


Fig.3

Fig.4

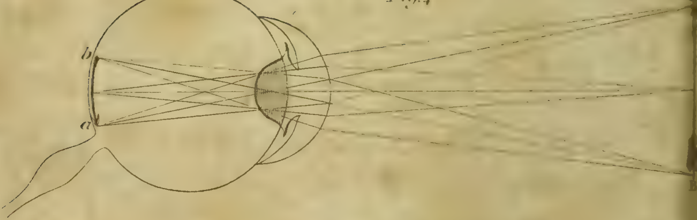


Fig.5

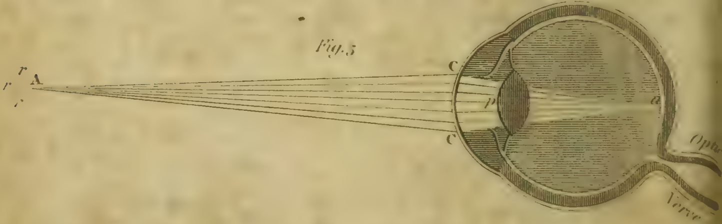
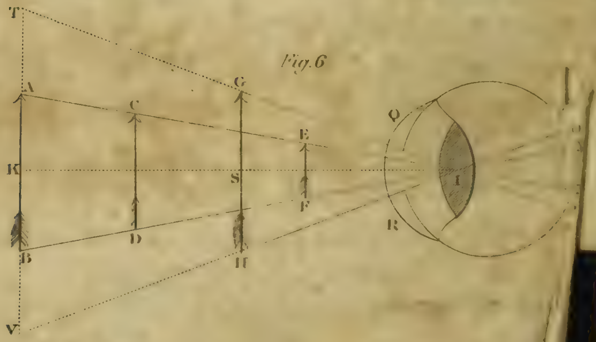


Fig.6



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will instantly be dispelled, as if by enchantment. *(He removes his hands).* Look up and behold the beauty, the majesty of Nature!

After this conversation, Mr. Vermont and his children proceeded gaily homewards. The sun having reached the end of his course, painted the west with the most brilliant colors; and the horizon, tinged with gold and purple, presented to the view a most magnificent spectacle.

## *Explanation of Plate* I.

*Fig.* 1. Section of the human eye, exhibiting the different humors of which it is composed.

*Fig.* 2. Front view of the human eye.

The aqueous humor which is situated in the fore part of the eye is about the density of common water, and has the same refractive power. The crystalline humor has very little more specific gravity than water, but its refractive power is to that of water as 14 to 13. The vitreous humor, again, which is most abundant, exceeds water but very little in its specific gravity, and in its refractive power. Thus it is obvious, that the rays of light must suffer three refractions in passing the humors of the eye. The cornea is of a globular form, and stands rather prominent, in order to take in a greater quantity of light. According to the principles of optics, parallel rays falling on a convex surface, are made to converge. Thus, let us suppose CD, *fig.* 3, two parallel rays, which fall on the eye at AB, and enter the pupil. The aqueous humor Q being of about the same density with water, the rays by this first refraction would be made to converge to the point F, at twice the diameter of the convex surface. This point, however, being beyond the bottom of the eye, it is necessary that some other convex surface of greater density should be interposed, to increase their convergence. This is effected by the crystalline humor NN, yet the rays would still be made to converge beyond the eye, were it not for the vitreous humor RR, which, being of a less refractive power than the former, and of a concave surface, where the rays pass into it from the crystalline, they are still farther refracted, and united at the bottom of the eye, at the point S.

It has been a matter of much doubt, by what means it happens that we see every object in its natural upright position, when we know it to be inverted on the organ of sensation. The most satisfactory answer that can be given to this is, that we do not see the picture which is formed at the bottom of the eye, but the object itself. The picture, or rather the impression made on the retina, is the means of seeing, and therefore it does not appear of material consequence on what part of the retina the impression is made. We in fact see the image in the direction of the ray which conveys to us the sensation, or rather in the direction of the axis of that pyramid, which a pencil of divergent rays forms in proceeding from any point of an object.

Thus, in *fig.* 4 [illegible], we see the point of the arrow (which is indeed depicted in the lower part of the eye) in the direction of the line a A, that is, in its proper upright position. On the contrary, we see the other extremity of the arrow (which is painted on the superior part of the retina) in the direction of b B, that is, at the lower end of the object. However, therefore, the image which is formed may appear inverted to a person inspecting a natural eye, still the eye itself discerns the object in its proper and natural position.

From every luminous point of a visible object, cones or pencils of light are emitted or reflected in every direction, but, to produce vision, it is necessary that they should be concentrated or conveyed to such a point as to make a forcible impression on the retina. Thus from the luminous body A, (*fig.* 5) the rays *r r r*, are sent in various directions. Those which fall upon the transparent cornea CC, are there reflected in such a manner as to enter the pupil at *p*, and in passing the crystalline lens or humor, they suffer a second refraction, and are conveyed to a point or focus at the point *a*, on the retina. Now it is evident, that if the rays could have passed the humors of the eye in their natural direction, that is, in the direction of the cone or pyramid CAC, they would have made upon the retina a very extensive but feeble impression, such as we know by experience, could not produce distinct vision. To obviate this, it is appointed by the all-wise Author of our existence, that, by the force of the refraction which they suffer in the eye, they should form another cone opposed to the first at its base, and the apex of which is at *a*, and thus an impression sufficiently forcible to produce distinct vision is made on the retina.

Artificial eyes are sold by the opticians, in which all the humors are made of different kinds of glass, and may be separated at pleasure. At the back part, where the retina is supposed in the natural eye to receive the converged rays, is placed a piece of ground glass, where the image from the opposed objects is represented in an inverted position, as in a camera obscura. The same effect may be produced with a natural eye, and the nature of vision may be thus experimentally demonstrated. If a bullock's eye is taken fresh, the posterior coats dexterously removed even to the vitreous humor, and if a piece of white paper is then placed at the part, the image of any bright object before the eye will be seen distinctly painted on the paper, but in an inverted position.

If the humors of the eye, through age or weakness, have shrunk or decayed, the cornea will then be too flat, and the rays not being sufficiently bent or refracted, arrive at the retina before they are united in a focus, and would meet, if not intercepted, in some place behind it. They therefore do not make an impression sufficiently correct and forcible, but form an indistinct picture on the bottom of the eye, and exhibit the object in a confused and imperfect manner. This defect of the eye is therefore remedied by a double convex lens, such as the common spectacle glasses, which, by causing the rays to converge sooner than they otherwise would, afford that aid to this defect of Nature which the circumstances of the case may require, the convexity of the glass being always proportioned, by one who is capable of directing in the choice of spectacles, to the deficiency in vision.

If, on the contrary, the cornea is too convex, the pencils of rays will unite in their foci before their arrival at the retina, and the image will also in this case be indistinct. This defect is remedied by concave glasses, which cause the rays to diverge, and consequently, by being properly adapted, will enable the eye to form the image in its proper place.

The rays of light being emitted or reflected from a visible object in all directions, it must be plain that some of them from every part of it must reach the eye. But though rays are reflected from every point of the object to every part of the surrounding space, yet it is evident that only those rays which pass through the pupil of the eye can affect the sense, and those rays also give the ideas of color, according to the properties of the bodies which transmit or reflect them.

As the direction in which the extreme pencils of light cross each other in the eye, bears a due proportion to the angle in which they are transmitted from the object to the eye, it is evident that the image formed upon the retina will be proportioned to the apparent magnitude; and thus we have our first ideas of the size and distance of bodies, which, however, in many cases are corrected by experience. The nearer any object is to the eye, the larger is the angle by which it will appear in the eye, and therefore the greater will be the seeming magnitude of that body. In *fig.* 6, let AB be an object viewed directly by the eye QR. From each extremity draw the lines AN and BM, intersecting each other at the crystalline humor at I. Then draw the line IK in the direction in which the eye is supposed to look at the object.

The angle AIB is then the optical or visual angle, and the line IK is called the optical axis, because it is the axis of the lens or crystalline humor continued to the object.

The apparent magnitude of objects then depending thus on the angle under which they are seen, will evidently vary according to their distances. Thus different objects, as AB, CD, EF, the real magnitudes of which are very unequal, may be situated at such distances from the eye as to have their apparent magnitudes all equal; for if they are situated at such distances that the rays AN, BM, shall touch the extremities of each, they will then all appear under the same optical angle, and the diameter MN of each image on the retina will consequently be equal.

In the same manner objects of equal magnitude, situated at unequal distances, will appear unequal. For let AB and GH, two objects of equal size, be placed before the eye at different distances IK and IS; draw the lines GP and HO crossing each other in I; then OP, the image formed by the object GH on the retina, is evidently of a greater diameter than the image MN, which represents the object AB: in other words, the object GH will appear as large as an object of the diameter TV, situated at the same place as the object AB.

To render the subject still clearer, suppose an object placed at the distance of two hundred yards, the angle which it forms in the eye will be twice as small as when it is one hundred yards off. Thus to whatever moderate distance the object is removed, the angle it forms in the eye will be proportionably less, and therefore the object will be diminished in the same proportion. Hence it follows, that objects situated at different distances, whose apparent magnitudes are equal, are to each other, as their distances from the eye; and by the same rule, equal objects situated directly before the eye, have their apparent magnitudes in a reciprocal proportion to their distances.

This last proposition must, however, be received with some allowance; for it is only applicable to very distant objects, and to those where the sense is not corrected by the judgment. For if the objects are near, we do not judge of their magnitude according to the visual angle. Thus if a man six feet high is seen at the distance of six feet under the very same angle as a dwarf only two feet high at the distance of two feet, still the dwarf will not appear so large as the man, because the sense is corrected by the judgment.

In most cases, however, where the distance is considerable, the rule will be found accurate; and as it has its foundation in nature, most of the phenomena of vision will be explained by having recourse to the principles here laid down. If the eye is placed upon a horizontal plain, the different parts of this plain will appear elevated in proportion to their distance, till at length they will appear upon a level with it. For, in proportion as the different parts are more distant, the rays which proceed from them form angles with the optical axis IK, *fig*. 6, more and more acute, and at length become almost parallel. This is the reason why, if we stand on the sea-shore, those parts of the ocean which are at a great distance appear elevated; for the globular form of the earth is not perceptible to the eye, and if it was, the apparent elevation of the sea is far greater than the arch which a segment of the globe would form, within any distance that our eyes are capable of reaching.

For the same reason, the distant parts of a long wall appear to a person who stands at one end, to curve or incline towards him. In the same manner the high wall of a lofty tower, seems to a spectator placed directly under it to bend over him, and threaten him with instant destruction. If any person inclined to make the experiment, will lie down on his back in such a situation, at the distance of five or six feet from the wall of which he contemplates the tremendous height, he will immediately be made sensible of the phenomenon.

If the eye is carried along, as in a boat, without being sensible of its own motion, the objects which are stationary on each side will appear to move in a contrary direction. Thus we attribute to the sun and the other heavenly bodies, a diurnal motion which only affects the earth we inhabit.

If two or three objects at a considerable distance, and on which the eye of the spectator is fixed, move with equal velocity past a third object which is at rest, the moving objects will appear to be actually at rest, and that which is really stationary will appear in motion. Thus the clouds which pass over the face of the moon appear at rest, while the moon itself appears to proceed rapidly along in an opposite direction. This happens because the eye, which is fixed upon the clouds, follow their motion mechanically, and therefore the moon appears to move and not the clouds, as in the boat we do not perceive its motion, but imagine that the banks are retiring behind us.

Such are the general principles upon

which vision is performed; but the sense of sight is limited not only with respect to distant objects, but with respect to those which are near. Every person will easily perceive, that if a book or any other object is held too close to the eye, the letters or the object will appear very indistinct and confused. This distance varies with respect to different eyes. Very near-sighted persons can see at the distance of one or two inches, but where the eye is in a sound state, the point of distinct vision varies from six to ten inches, or eight inches as a medium.

From the principles laid down, it may easily be understood why very minute objects are imperceptible to the naked eye. If those objects could, consistently with distinct vision, be brought near to the eye, they would be perceived as well as by the aid of a microscope; hence some very near-sighted persons may be said to have microscopic eyes; but at six or eight inches, the limit of distinct vision, these objects subtend too small an angle to be perceptible.

Opticians assert that the eye is not capable of perceiving any object which subtends an angle of less than half a minute of a degree. The image on the retina, is in this case less than the $\frac{1}{7200}$ part of an inch, and the object itself at six inches distance less than $\frac{1}{1200}$ part of an inch broad. All smaller objects are invisible.

All very distant objects, upon the same principles, appear indistinct; for their images on the retina are so extremely small, that the distinction of parts is not perceptible. Thus, if a man of six feet stature is viewed at the distance of a mile, his image on the retina will not be more than the $\frac{1}{1000}$ part of an inch in length. We cannot be surprised, therefore, if the eye can discern nothing of his features or the minuter parts of his body.

Distant objects, however, appear not only indistinct but obscure, and this last effect proceeds from a deficiency of light, very many of the rays being intercepted in their passage through the air. Hence the difference in the appearance of such objects in a dark, cloudy day, when the air is impregnated with vapors, from that which they assume when the sun shines full and strong upon them.

With a single glass the defects in sight, with respect to many objects either too near, or at too great a distance for the persons labouring under them, are remedied; but there are cases where the object is so far distant, or so minute, that, though its outline may reach the eye, its parts must still, even with the aid of a single lens, be indistinctly perceived. The art of man has discovered a remedy in a great degree for this imperfection, and by means of a combination of glasses, has opened a wide field for his researches into the wonders of Nature; he can now trace the limbs of an insect invisible to the naked eye, or he can make the celestial objects appear to him as if their distance had been on a sudden diminished by many millions of miles.

## THIRD CONVERSATION.

### OF THE EARS, OR THE ORGANS OF HEARING.

The following day, Mr. Vermont employed the morning in shewing his children the experiment with the camera obscura; and towards evening he walked with them into the pleasure grounds.

After rambling for some time, he sat down in the shade of a spreading tree, and his young companions soon seated themselves beside him. A nightingale concealed in a horn-beam hedge, poured forth his melodious strains, which did not escape the notice of the children. They durst not speak, lest they should frighten the bird away. Eliza in particular, remained motionless with admiration; she lost not a single note of the winged chorister; but she was vexed that she could not see the bird whose song gave her so much delight.

At length she rose, and so did Alfred. Eliza went softly towards the hedge where the nightingale was perched; Alfred followed, and the bird flew away. Alfred accused his sister of being the cause of this disappointment, and Eliza retorted the charge. Both of them, in some confusion, returned to their father, and again seated themselves by his side.

*Mr. Vermont.* You are justly punished for your too great curiosity; but listen—the nightingale sings again.

*Alfred.* But papa, what bird is that which is singing at a greater distance, and keeps continually repeating *yo, yo, yo?*

*Mr. Vermont.* It is called a blackbird, from the colour which predominates in its plumage.

*Eliza.* Oh! how I should like to see it. Perhaps it would not be so wild as the nightingale. Let us go and see.

*Mr. Vermont.* You would only lose your trouble a second time.

*Alfred.* Then birds must have very good ears, to hear a person's footsteps at such a distance.

*Eliza.* And while they are singing too!

*Mr. Vermont.* Yes, my dears. As birds are exposed to a thousand dangers, it was but just that Nature should richly endow them with the faculty of hearing, in order to enable them to guard against accidents.

*Alfred.* But where are the ears of birds? We cannot see them.

*Mr. Vermont.* That is not surprising: they are covered with feathers.

*Alfred.* What for, papa?

*Mr. Vermont.* Because, if birds had long ears like certain quadrupeds, they could not cut the air with such velocity as at present. Their ears would be like sails, that would drive them back when they wanted to go forward.

*Eliza.* But papa, where are their ears situated?

*Mr. Vermont.* In the head, near the eyes. This position is extremely advantageous, for sight and hearing are very closely connected. They are two sentinels which watch together for the safety of the individual!

*Richard.* I should imagine, papa, that the ear is a much more vigilant sentinel than the eye.

*Eliza.* Our eyes close when we sleep.

*Mr. Vermont.* And our ears never close. When all the other senses slumber, the ear is in some degree awake. It is continually on the alert, on the listen. If it hears slight noises, sounds to which it is accustomed, it does not alarm us; but if the noise is violent or extraordinary, it rouses us without hesitation, and seems to say: there is danger!

*Eliza.* That is exactly the case with me when there is a thunder-storm at night. As long as the claps of thunder are not loud, my ear does not apprize me of them; it lets me sleep soundly; but when the peals are so violent as to shake the house, it never fails to waken me, which vexes me a good deal.

*Alfred.* I wake too sometimes, when it thunders, and then I envy the deafness of old Jonathan. But papa, how comes it that Jonathan is deaf?—His ears look exactly like ours.

*Mr. Vermont.* Yes, externally; but the defect which occasions deafness is in the interior of the organ, and for that reason inaccessible to the hand that might otherwise be capable of curing it.

*Richard.* Then, papa, is it for some useful purpose or only for ornament, that our ears have received their present external conformation?

*Mr. Vermont.* Nothing in Nature was made without some wise design, my dear. The ear is admirably formed to collect from every side the vague impressions of sound, and afterwards to convey them gently to the internal organ of hearing. The first thing which strikes us when we look at it, is a kind of chamber with its winding cavities. All these little hollows, all these small eminences have their use. It is these that modify sounds, that soften them and prevent confusion. A convincing proof of the great advantage and convenience of this external structure of the ear, is, that if by any accident a person were deprived of it, he would hear nothing but confused sounds, accompanied with a certain murmuring similar to that caused by the falling of water.

*Alfred.* That is exactly the noise which I hear when I press my two hands closely to my ears. It seems as if there was a water-fall or a water-mill at work by my side.

*Mr. Vermont.* It is now my turn to ask you a question, my dears.

*Richard.* Well, papa, what is it? I'll answer it if not too difficult.

*Mr. Vermont.* What is the ear made of?

*Eliza.* It is made of flesh.

*Mr. Vermont.* I am much mistaken if I don't feel something harder.

*Alfred.* And so do I.

*Mr. Vermont.* What do you feel then? Is it a bone?

*Richard.* Oh! no; a bone would be harder than that.

*Mr. Vermont.* It is a substance called cartilage or gristle, and which is best adapted for the situation in which it is placed: for if the ear had been a bony substance, it would have occasioned many inconveniences, and been liable to be broken by a variety of accidents. Were it composed of flesh, it would always remain flaccid; it would absorb and retard, if not entirely stop the progressive motion of sounds; whereas by its hardness and the hollows in its polished surface, it allows them an easy passage, by whirling them round as it were, and giving them a regular reflection, such as they receive in vaults, grottos or musical instruments, which tend to increase sounds or to render them agreeable, and some of which transmit the slightest noise or murmur to a great distance

*Richard.* The ears of animals, papa,

don't appear to have so many windings as ours.

*Mr. Vermont.* That is true; but quadrupeds whose external ear differing in conformation from the human ear, resembles a truncated cone or cornet, have received from Nature a faculty which supplies the deficiency in respect to the conformation of this part. Their ears are moveable. By the contraction of the different muscles, they can erect and turn them towards the quarter whence the sound proceeds; so that a great quantity of sonorous rays enters the auditory canal. But this is not the case with man. Notwithstanding the small muscles with which his ear is provided, it is almost immoveable*, and he would be liable to lose a great portion of sounds, did not the windings and eminences forming the chamber of the ear, stop, reverberate and direct them towards the entrance of the auditory canal. Of this any one may easily convince himself by inspecting the part, and by examining, in particular, with what art all these eminences by their position direct the sound toward this canal as to one common centre; so that very few sonorous rays which strike the chamber of the ear, escape that organ. The consequence is, that of all animals man receives proportionably the greatest quantity of sound; the ear of quadrupeds having a less advantageous configuration. Now birds, reptiles, and fishes, in which this external part is wholly wanting, cannot receive so large a quantity of sonorous rays as quadrupeds. Perhaps, however,

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* In the second volume of the Philosophical Transactions for 1800, is recorded a curious case, in which, notwithstanding the almost total loss of the membrane of the drum of the ear, supposed to be essential to hearing, that sense was retained in a very considerable degree. In this instance we are told, the external ear had acquired a distinct motion upward and backward, which was observable whenever the patient listened to

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any thing which he did not distinctly hear. When he was addressed in a whisper, the ear was seen immediately to move; when the tone of voice was louder, it then remained altogether motionless.

the thin bones of the skull of birds, which are highly susceptible of the vibrations of sound, may partly compensate for this deficiency, and render their hearing more delicate and distinct.

*Richard.* But papa, when sounds have entered the channel of the ear, where do they go to?

*Mr. Vermont.* Before we proceed any farther, let us for a moment consider this winding channel, which begins at the bottom of the external ear. Formed partly by a cartilage and partly by bone, it is covered with a skin containing an infinite multitude of glands which furnish a thick, yellow, unctuous, wax-like humor, that adheres to its sides. Nature has formed this bitter wax in the channel of the ear, that if small insects attempt to penetrate into it, they may be caught as if with bird-lime. It is a remarkable circumstance, that this viscous humor is constantly found in the ears, if not of all, at least of most of the species of animals whose ears are formed like a funnel, and in which the channel is long and wide enough to admit the earwig and other insects. It is not found in birds whose ears are covered with feathers, and in which the tympanum is very little sunk in the head; for it would be unnecessary to defend ears of little depth and so well protected, with such a humor. But we derive another advantage from this wax-like humor. By lining the auditory canal, it tends, by its consistence, to prevent any useless, and perhaps pernicious impression, which the rays and vibrations of sound would produce upon the sides of that canal. If it were cleared away with too great care, we should have too acute and too strong a perception of sound. The sound would then be lost and dissipated in its way through the canal; whereas, deadened by the thick and soft matter with which it is lined, it proceeds and acts principally upon the membrane of the drum or tympanum, which I am going to describe.

*Richard.* Where is the membrane of the tympanum situated, papa; how is it made, and what is its use?

*Mr. Vermont.* The membrane of the tympanum is situated at the extremity of the auditory canal, and separates the external from the internal ear. It is of an extremely fine and delicate texture. It is susceptible not only of being agitated by the air, like the parchment of a drum that is struck and that can give only one kind of sound, but it may be more or less distended, and is thus adapted to reflect every possible tone. Behind this membrane is a cavity hewn out of a rock, that is, wrought into the temporal bone, the hardest of the body. In this cavity, denominated the *tympanum* or drum, there seems to be an echo, in which the sound is reflected with great precision. This cavity contains the little bones of the ear, which are four in number, and from their form have received the names of the *malleus* or hammer, the *incus* or anvil, the roundish or oval bone, and the *stapes* or stirrup. The body of the malleus is placed in the upper part of the tympanum, and a long process called the handle descends between the laminæ of the membranes of the tympanum, where it is accurately fixed. It is articulated with the incus by means of two projecting ridges and a furrow between them. The incus, which consists of a body and two legs, and is not unlike a tooth with a double root, exceeds the other little bones of the ear in size and strength; its body is connected with the malleus; its shorter leg is placed at the entrance of the canal, which leads to what is called the mastoid process; its longer leg takes the same direction with the handle of the malleus, to which it is attached inwardly by a ligament, and being bent inwards at its termination, receives the small oval bone, and by this is united with the stapes. The two legs of the latter are bent nearly into a circle, and where they unite at the basis cover the *fenestra ovalis,* or oval window. This appellation is given to one of the two apertures in the cavity of the tympanum, for the purpose of communicating sounds to the last cavity of the internal ear, called the labyrinth.

*Richard.* What, papa, is there another cavity beyond that of the tympanum?

*Mr. Vermont.* Yes, my dear; this cavity is even composed of three parts: the *vestibule,* three *semicircular* canals, and the *cochlea.* But we have not yet done with the tympanum. Besides the fenestra ovalis, it has another aperture, called the *fenestra rotunda,* which also communicates with the labyrinth. In order to reflect sounds still better and to augment their force, Nature has moreover formed in the cavity of the tympanum, various windings or hollows called the mastoid cells; and to renew the air in them, she has there placed an aperture by which the cavity of the tympanum communicates with the back part of the mouth, and which is called the Eustachian tube*.

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* Paley, in treating of the ear, gives with his usual ingenuity, the following reasons why no other contrivance could have been adopted instead of the Eusta-

*Richard.* I should think, papa, that if there were a communication between the back part of the mouth and the cavity of the tympanum, we might hear by our mouths.

*Mr. Vermont.* And how often is it the case that we open our mouths to hear better! If we are listening to an orator addressing a numerous assembly, we open our mouths as if by instinct. Accordingly

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chian tube. "It would not have done," says he, "to have had a vacuum in the cavity of the tympanum; for in that case the pressure of the atmosphere from without would have burst the membrane which covered it. Nor would it have done to have filled the cavity with lymph or any other secretion; which would necessarily have obstructed both the vibration of the membrane and the play of the small bones. Nor lastly, would it have done to have occupied the space with confined air, because the expansion of that air by heat, or its contraction by cold, would have distended or relaxed the covering membrane, in a degree inconsistent with the purpose which it was designed to execute. The only remaining expedient, and that for which the Eustachian tube serves, is to open to this cavity a communication with the external air. In one word, it exactly answers the purpose of the hole in a drum."

we say of any person who listens with great attention, that *he listens open mouthed.* This circumstance has not escaped the notice of one of our greatest dramatic writers, Shakspeare, from whose works I have now and then read you passages, and who makes one of his characters say, in the play of King John,

> I saw a smith stand with his hammer thus,
> The whilst his iron did on th' anvil cool,
> With open mouth swallowing a tailor's news.

I have described to you, my dears, the formation of the tympanum, the bones which it contains, and the apertures of that cavity. I shall now explain what takes place when the vibrations of the air strike against the membrane of this drum placed at the extremity of the auditory canal. The handle of the malleus attached to this membrane is affected by the shaking which succeeds. This shaking is stronger or weaker according as the sound is more or less loud: but when this bone is thus set in motion, it soon communicates the same impression to the incus, which is articulated with its upper part. The latter transmits the same motion to the stapes, to which its longer leg is fastened, and the stapes communicates this same impression to the labyrinth, by the fenestra ovalis, which is covered by its base. Thus the movements of the membrane or parchment of the drum are transmitted through a kind of chain to the window of the labyrinth.

*Richard.* What is the meaning of the labyrinth, papa?

*Mr. Vermont.* I said just now that this is the appellation given to the last cavity of the ear. The labyrinth is contiguous to the cavity of the tympanum, and it is divided, as I have already observed, into three different parts; that is to say, the vestibule, the semicircular canals, and the cochlea. The vestibule, thus named because it serves for the porch or entrance to the semicircular canals and the upper part of the cochlea, receives the impression of sound by means of the fenestra ovalis: but as, on the one hand, the upper part of the cochlea, and, on the other, the three semicircular canals, open into the vestibule, the air cannot be agitated in that cavity, without being soon agitated also in these other parts. At the same time, a similar commotion takes place in the air contained in the lower part of the cochlea, by means of the fenestra rotunda, to which it is contiguous; so that the nerves of all these parts receive the impressions of sound and transmit them to the brain.

*Richard.* I should never have supposed that sounds had such a long journey to perform before they arrived there.

*Mr. Vermont.* Of all the parts of the ear, the cochlea is the most remarkable. It is a canal which takes a spiral course not unlike the shell of a snail, and is divided by a very thin lamina or septum of cords, which keeps decreasing from the base to the top. These diminutive cords, which Muschenbroek and other anatomists have compared with the strings of a lyre, may, from their position, be struck on both sides at the same time, by the air of the upper spiral, which communicates with the vestibule, and by that of the lower spiral, which has a communication with the cavity of the tympanum by the fenestra ovalis. The air acting thus on either side of these cords, produces a motion in those which are in unison with the sonorous rays, nearly in the same manner as the sound of one instrument excites a tremulous motion in the cords of another, which are adjusted to the same tone. Hence it follows, that, as in stringed instruments, the longest cords give the gravest sounds, and the shortest produce the most acute, so the lower part of the partition of the cochlea, being the broadest, must serve for the perception of the graver sounds, while the more acute are transmitted to the brain by the action of the upper part of this partition, which is narrower.

*Eliza.* For my part, what appears most striking to me in the description of the ear, is the hammer, the anvil and the stirrup.

Is it possible that so many bones are set in motion to convey sounds to the labyrinth?

*Mr. Vermont.* Yes, my dear: and it is very remarkable, that while all the other bones grow with the body, those of the ear are exactly of the same size in children as in adults. The reason of this undoubtedly is, that the instruments of hearing may be uniform for persons of all ages, and that man, from his infancy, may have the full enjoyment of so necessary an organ.

*Alfred.* See there now to what the flight of the nightingale has led us. To that we are indirectly indebted for what papa has been telling us.

*Eliza.* She is still singing. Let us listen to her. How her melodious strains delight the ear!

*Mr. Vermont.* It is not only by the song of birds that Nature designed to gratify our ear. Only listen. Do you hear the gentle murmur produced by the rustling of the leaves?

*All.* Yes, papa.

*Mr. Vermont.* Do you hear the brook which runs through the grove close to us?

*All.* Yes, papa.

*Mr. Vermont.* These sounds are infinitely diversified in the country, and from all of them together results an enchanting harmony. Go, Alfred, break off a branch of that horn-beam, and bring it to me. *(Alfred obeys.)* Do you see how these leaves are formed?

*Alfred.* They are oval and full of wrinkles.

*Mr. Vermont.* Do you see these little indentations, which form a sort of scollop round them?

*Alfred.* Yes, papa.

*Mr. Vermont.* Now look at this leaf of the chesnut.

*Alfred.* It is totally different. You would suppose it to be several leaves joined together, the indentations are so large and deep.

*Mr. Vermont.* There are other leaves entirely different from these. You know those of the willow. There are some, as those of the pine, which are called *filiform,* because they are small and sharp like needles. Others are in the shape of a heart, as those of the lilach. In short, there is an infinite variety of leaves.

*Alfred.* This variety was certainly intended to gratify the eye.

*Mr. Vermont.* Yes, and the ear also.

*Richard.* How so, papa? I can't comprehend that.

*Mr. Vermont.* When the wind plays among the foliage of a tree, it produces a different sound, according to the form of its leaves: and as each kind of tree has a different murmur, you would be able to distinguish trees by these sounds if you were more accustomed to hear them. The wind whistles in the pine, it trembles in the poplar, it sounds hollow in the oak. These murmurs are so various, that we have not words to express them. They are, nevertheless, the soul of rural scenery, and I have often taken great delight in studying them*.

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* "The very sounds of plants are not to be overlooked; for when agitated by the winds, most of them emit sounds peculiar to themselves, and which produce highly agreeable harmonies or contrasts with the situations in which they are accustomed to grow. In India the hollow canes of the bamboo, which shade the banks of the rivers, imitate, as they rustle against each other, the noise of the working of a ship; and the pods of the cinnamon, agitated by the winds on the summit of a mountain, the clack of a mill. The moveable leaves of the poplar convey to the ear in the midst of the forest the babbling of the brooks. The verdant meads and the calm forests, fanned by the zephyrs, represent in the depths of the vallies and on the sides of the hills, the undulations and the murmurs of the waves of the sea breaking against the shore. The early inhabitants of the globe, struck with these mysterious sounds, imagined that they heard oracles issue from the trunks of the oaks, and that the Nymphs and Dryads, enclosed in their rugged bark, inhabited the mountains of Dodona."—*St. Pierre's Studies of Nature.*

## FOURTH CONVERSATION.

### OF THE SENSES OF SMELL, TASTE, AND TOUCH.

*Mr. Vermont.* You have now some idea of the mechanism of the organs of sight and hearing: we have yet to consider those of the other senses; but where is Eliza?

*Richard.* She has been to take a look at the garden. There she comes with a flower in her hand.

*Mr. Vermont.* She must certainly have supposed that we were going to speak of the smell.

*Eliza.* Papa, all the carnations in the garden are open; I thought I might take this one: what a delightful smell it has! *(She holds it to her papa's nose, and then to Richard's and Alfred's).*

*Mr. Vermont.* We have smelt it one after another, and the sense has been agreeably affected by its odor. This carnation, my dears, affords me an opportunity of speaking to you concerning the sense of smell, of which the inside of the nose is the organ; and of giving you an idea of the art with which it is contrived to receive that sensation.

*Richard.* Ah! papa, I am impatient to learn how the inside of the nose is formed.

*Mr. Vermont.* Just beyond the aperture of the nostrils, which is very narrow, the interior of the nose forms two cavities, separated like the nostrils by a partition. These cavities expand gradually from their entrance, and at length unite into one, which communicates with the mouth*.

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* "In order to render the sense of smelling more acute," observes Dr. Gregory in his Economy of Nature, "the internal cavity of the nose is variously contorted and enlarged, by a communication with several adjoining cavities, so as to increase very much the surface on which the sentient membrane is distributed. The cavities with which the nostril communicates are called sinuses; these are the frontal, which is seated in the frontal bone under the eyebrows; the ethmoid, which is a spongy cavity in the ethmoid or sieve-like bone; and

This whole cavity is lined with a membrane called the pituitary membrane. It is of a spongy nature, and is composed of an intermixture of vessels, nerves, and a great quantity of glands. This membrane is furnished with papillæ, which are composed of the extremities of these vessels; that is, of small nervous tubercles, which are the organ of smell, and from which the viscid mucus of the nose is secreted.

*Richard.* What is the purpose of the humors with which the nose is always filled, papa?

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the maxillary, which is chiefly formed in the maxillary bone, and lies immediately above the double teeth of the upper jaw. In animals which smell more acutely, these provisions for enlarging the internal surface of the nostril are still more remarkable."

"This sense," the same author remarks, "is far less acute in man than in many other animals. Thus the dog possesses a power of smelling of which we can scarcely form a conception, and which we happily do not possess. The sense of smelling in man is such as to fit him for deriving enjoyment from a diversity of scents, particularly those of flowers, to which dogs and other animals which do not feed on herbs, seem perfectly insensible."

*Mr. Vermont.* To keep the little nervous tubercles in the state of suppleness which is necessary for the performance of their office. Among these useful humors must be reckoned the tears conducted by the lacrymal canal into the nose.

*Richard.* It appears that it is the nerves which perform the most important part in the action of our organs. When you were describing the eyes, you told us that it is on the extremity of the optic nerve that objects are painted. When you treated of hearing, you said that the labyrinth is encircled by the branches of the auditory nerve, and now we find that there is another nerve for smelling.

*Mr. Vermont.* This is called the olfactory nerve. The great number of its fibres is what produces the extraordinary quantity of glands in the pituitary membrane.

*Eliza.* You sneezed just now, papa; what is the cause of sneezing?

*Mr. Vermont.* Besides the olfactory nerve, a branch of the optic nerve enters the nose. It is the communication of this small nerve with that of smelling which makes our eyes water when we have inhaled very strong odors; and as this nerve is, in its principle, connected with the nerves of the organs of respiration, whenever it is powerfully affected, it produces in those organs the convulsive movements of sneezing. Now, in order to comprehend the mechanism of smelling, imagine that all objects which have any odor, give out particles imperceptible to the eye, but which we should perceive if our sight were more acute. The prodigious quantity of these volatile particles, incessantly exhaling from an odorous body, and that without causing any sensible diminution of its weight, is a proof of a division of matter which fills the mind with astonishment. These particles float in the air unperceived like the dust in a room, which is not seen except in the sunshine.

*Richard.* What are these particles composed of? If they were all alike, there would be but one kind of smell.

*Mr. Vermont.* Salt is always the agent, or at least the instrument that produces the sensation. All salts indiscriminately excite tastes; but they must be volatile in order to form odors: it is the difference of the salts that constitutes the variety of smells.

*Richard.* And how are these odorous particles conveyed into the cavities of the nose?

*Mr. Vermont.* By the movement of respiration, which causes the air to pass and repass incessantly through these cavities, on its way to and from the lungs. This is the reason why persons who have the passage of the nose stopped by a cold, and are obliged to breathe through the mouth, at such times lose their smell. The passage of the air through the cavities of the nose, likewise serves sometimes to cleanse those cavities of any matters by which it is choaked up, as when the air of the lungs is expelled through it with violence, or when you blow your nose, or sneeze.

*Richard.* I should think too that if the air did not pass through the cavities of the nose, we should be obliged to breathe through the mouth, and consequently we should always have it open.

*Eliza.* O fie! what an ugly look that would have.

*Mr. Vermont.* If the air had not a continual passage through the nose, infants when they first come into the world, could not suck. Thus, when a child is too long at the breast, the mother or nurse, if she wishes to take it away, need only apply a gentle pressure to the nose, when it is immediately obliged to loose its hold. But let us continue our walk.

*Alfred.* Papa, the gate of the garden is open.

*Mr. Vermont.* Well, let us take a turn in it; we may there speak of taste, and you may yourselves judge of the utility of this new sense, while you eat some of the fruit which it affords in such abundance.

*Alfred.* Oh! how delightful! Look,

sister, at those gooseberry bushes, which have more fruit than leaves. See what fine large red gooseberries.

*Eliza.* What is the reason, papa, that gooseberries turn red as they ripen?

*Mr. Vermont.* It is not easy to explain to you in what manner this takes place; but I can tell you why, or rather you have no need of that information. Look at that bush; some of the berries are still green and others are red. Which of these are fit to eat?

*Eliza.* The red ones.

*Mr. Vermont.* And if all the berries continued green, how would you know which were fit to eat?

*Eliza.* I should be a good deal puzzled, and should certainly mistake them.

*Mr. Vermont.* It is therefore very fortunate that, by their change of colour, they afford you a medium by which to distinguish the one from the other.

*Alfred.* Is not what you have said of red gooseberries applicable also to cherries?

*Mr. Vermont.* Certainly. If cherries

retained their original green colour, we should be obliged to climb the trees every day to taste whether they were ripe. Providence has relieved us from this difficulty by giving ripe cherries a livery, which enables us to perceive them at a considerable distance. The red color, by catching the eye, invites the hand to gather the fruit, which, when arrived at maturity, cannot be hurtful, and consequently ought no longer to be concealed from our view.

*Richard.* Papa, you are right. As long as cherries are unripe they are hidden as it were, among the leaves: We don't perceive them till they turn red.

*Mr. Vermont.* It is the same with all other kinds of fruit. Before they are ripe, they scarcely strike the eye at all. They are of the same color as the leaves ; but, as they advance to maturity, Providence apprizes us of this circumstance in various ways. It clothes them with a color which forms a striking contrast with the verdure of the trees ; it paints them with various shades of red, as the cherry ; or a beautiful violet, as the plumb; or a yellow, deeper or lighter, as the lemon and the orange; or a fine azure, as certain species of figs; or a rosé color, on a carnation ground, as the peach. It would be impossible to calculate the infinite number of tints employed by Nature in the mere clothing of the fruits which she every season so profusely bestows. Neither is she content with apprizing our sight of the period of their maturity; she frequently gives the same intimation by means of the fragrance with which she has perfumed them. It is the smell that judges of the maturity of the melon, as well as of that of several other fruits.

*Alfred.* Oh, papa! you make my mouth water. I can fancy that I smell at this moment the fragrant odor of melons, peaches, pears, plumbs, oranges——

*Mr. Vermont.* To the information given us by the sight and smell, is almost always added that which we receive from the touch. Ripe fruit grows soft, and thus apprizes our fingers of its maturity, in the same manner as its color informs the eye.

*Eliza.* I remember, indeed, that when pears were in season, I have often felt them, to judge whether they were ripe.

*Mr. Vermont.* The last information is given by the taste, which finally decides the matter. Fruits as they ripen, acquire a sweet taste, which pleases the most difficult palate. This sweet taste succeeds the sharpness and acidity which they had before. Do you not admire in all this a particular attention of Nature to our gratification?

*Alfred.* Yes, papa.

*Mr. Vermont.* Look round you, my dears. Observe by the side of those red gooseberries, others which are but just formed, and which will not be red for a month to come.—Look at that bed of pease with their green pods, while their stems are still covered with blossoms.—Examine these pretty borders of strawberries. Amidst their verdant tufts appear at once ripe strawberries and star-shaped flowers.—Look at that honeysuckle climbing up the trellis. The ground is strewed with its flowers, but later blossoms still adorn its branches. By a wise dispensation of Providence all the flowers of a shrub do not blow on the same day, neither do all its fruits ripen at once.

*Alfred.* Indeed, if all the fruit of a tree ripened at once, we should not know what to do with it; it is much better to have the enjoyment of it for a longer time. Papa, there is a row of small shrubs which look something like brambles.

*Mr. Vermont.* And they actually belong to that family, but thanks to a good disposition and attention to their culture, they produce very pleasant fruit. Those are raspberries.

*Eliza.* Along that wall, papa, I see trees spread out like fans, with leaves resembling those of the willow.

*Mr. Vermont.* Those, my dear, are peach trees; their fruit will not be ripe in less than two or three months. You know their exquisite taste. Peaches are among fruit what roses are among flowers.

*Richard.* Who would suppose that those little green berries would swell out into beautiful peaches, equally splendid in color and delicious in taste.

*Eliza.* But why are those trees confined and nailed with such uniformity against the wall ?—Why not suffer them to grow in the middle of the garden, like those stately pear trees ?

*Mr. Vermont.* It is not from any desire to mortify those trees that they are thus trained in espalier ; it is, on the contrary, to place them in a more advantageous manner, to expose them more to the sun's rays, to shelter them from the north winds, which might greatly injure them, and shake off the fruit.

*Alfred.* That would be very difficult ; I perceive, on touching one of these young peaches, that they are strongly attached to the branch.

*Mr. Vermont.* Yes, at present they are ; but as the peaches ripen, they adhere with less tenacity to the branch which supports them. At length, when a peach has arrived at the last stage of maturity, this may be known, not only from its color, but also from its falling into your hand, if you but touch it ever so gently.

*Alfred.* Oh ! if that be the case, 'tis perfectly right to shelter them from the wind.

*Eliza.* I was very fond of peaches before, but what papa has just told us makes me like them still better. Ah ! how charming it will be to come and gather them when they are ripe ! This will be so much the more pleasing as the branches are just of my height.

*Mr. Vermont.* It is to be observed, that the peach tree, if it were even in the open ground, never attains a great height like the chesnut or walnut-tree : its fruit would run too many risks, were they to ripen at such an elevation.

*Richard.* Indeed chesnuts and walnuts are enclosed, the one in a tough skin, and the other in a shell, capable of withstanding a fall ; but if peaches were to drop from such a height, they would be mashed into marmalade.

*Mr. Vermont.* And then Eliza could not climb up the tree to gather them.

*Alfred.* And we durst not knock them dawn with sticks like walnuts, or pelt them with stones, as we do chesnuts*.

*Eliza.* Are there different kinds of peaches, papa?

*Mr. Vermont.* Yes, to be sure. There is even a greater variety of this species of fruit than many others. We might say that Nature has taken great pains to gratify the delicacy of our taste by the extreme variety of savors; that of our smell by the extreme variety of fragrant odors;

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* "Our fruit-trees are easy to climb, and differ in this respect from most of the forest-trees. All those that produce fruits which are soft when ripe, and would be liable to be bruised in falling, as the fig, the mulberry, the peach, the apricot, present them at a small distance from the ground: those, on the contrary, that yield hard fruits, which run no risk of sustaining injury by a fall, carry them at a great elevation, as the walnut, the chesnut, and the cocoa."—*St. Pierre's Studies of Nature.*

and that of our sight, by the extreme variety of forms.

*Alfred.* These are pear-trees, I believe, papa: are they not?

*Mr. Vermont.* They may be easily known by the roughness of their leaves, and the shape of their fruit, which is already quite formed, though it will not ripen till towards autumn.

*Eliza.* So then there are fruits for every season?

*Mr. Vermont.* Yes, my dear; and what is still more admirable than the abundance, though that is almost a prodigy, is the wise distribution which has been made of all these productions, according to the wants of the seasons and climates, during winter. When the earth is at rest, and ceases to produce, in order to recover new juices, we enjoy an ample supply both of fruits and vegetables, that will keep a considerable time. In summer, the earth is daily bestowing fresh bounties; and in proportion as the heat of the sun becomes more intense, she seems more attentive to afford us cooling fruits, such as melons, peaches, and pears. The same connection which subsists between the fruits and the season is also observable between them and the climates. As we advance towards those regions, whose inhabitants continually see the sun pass over their heads, we find not only a profusion of fruits that dissolve like the melon, but such as are cold, acid, and full of water, capable of cooling their too highly rarefied blood. Such are limes, lemons, oranges, and ananas.

We have been led, my dears, into a long conversation on fruits; I did intend to have given you some account of the organ of taste, and we have only spoken of the objects which please it: but we shall return at some future opportunity to this subject; and with respect to the touch, I shall take occasion to speak of it more in detail when we come to the use and mechanism of the hand.

## FIFTH CONVERSATION.

### OF THE BONES, AND THOSE OF THE SPINE AND OF THE HEAD IN PARTICULAR.

*Eliza.* Papa, will you tell us something more about the structure of the human body to-day?

*Mr. Vermont.* Yes, my dear. It is an inexhaustible subject, and deserves, in every respect, a complete investigation. I shall to-day call your attention to the infinite art manifest both in the construction and in the arrangement of the bones. You know that the bones are to the human body what the wood-work is to a house. They support its various parts; without them the whole body would sink with its own weight; it would form a shapeless mass, and be incapable of any regular motion.

*Alfred.* The bones, indeed, are absolutely necessary for motion, and it is easy to see that they are wonderfully arranged with regard to each other.

*Mr. Vermont.* Is it possible, my dears, to survey without admiration, this great number of bones attached to each other, which ascend from the feet to the head with such order, and are inserted in one another with such art? United, without touching, lest they should be worn by the friction; and separated, but still not disunited, that they may bend upon occasion, without parting—what an edifice!—what architecture!—Observe in the first place, how the whole is supported by two solid, though flexible pedestals, the feet; each surmounted by a double column, composed of the two bones of the leg, the *tibia* and the *fibula,* articulated with each other, and with the heel at their lower extremities, and, in like manner, articulated at their upper extremities with each other, and the *os femoris,* or thigh bone, which corresponds with them.

For the sake of brevity, I shall pass over the remarkable structure of the patella or knee-pan*. Hence the two thigh bones

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[*] "The patella or knee-pan," says Paley, "is a curious little bone; in its form and office unlike any other bone in the body. It is circular, the size of a crown-piece, pretty thick, a little convex on both sides, and covered with a smooth cartilage. It lies upon the front of the knee; and the powerful tendons by which the leg is brought forward, pass through it, (or rather it makes a part of their continuation) from their origin in the thigh to their insertion in the tibia. It protects both the tendon and the joint from any injury which either might suffer, by the rubbing of one against the other, or by the pressure of unequal surfaces. It also gives to the tendons a very considerable mechanical advantage, by altering the line of their direction, and by advancing it farther out from their centre of motion; and this upon the principles of the resolution of force, upon which principles all machinery is founded. But what is most observable in it is, that it appears to be supplemental as it were to the frame; added as it should seem afterward; not quite necessary, but very convenient. It is separate from the other bones; that is, it is not connected with any other bones by the common mode of union. It is soft, or hardly formed in infancy; and produced by an ossification, of the inception or progress of which no account can be given from the structure or exercise of the part."

which are single columns, ascend obliquely to the hip bones, where they meet two other bony substances, which are there imbedded with them, and are attached together before, forming a kind of circular basin, destined to support the intestines, and to prevent them from falling below their natural situation.

A new subject of admiration here presents itself. Between the two hip bones, rises a seventh column, which ascends in stories from its insertion in those two bones, to the posterior part of the head, where the top of it is infixed in the base of the cranium.

This wonderful column, denominated the *spine,* is not all of one piece, like the six others, but a kind of mosaic work, composed of several flat bones nearly of a triangular figure, and perforated to allow a passage to the spinal marrow. The lowermost is a kind of reversed pyramid, the point of which is inserted between the two hips, and is denominated *os sacrum.* All the other small bones, twenty-four in number, are called *vertebræ,* or turning bones, in order to express the flexibility of their nature.

*Richard.* Do you intend, papa, to treat of all the bones of the human body?

*Mr. Vermont.* No, my dear, they are much too numerous for that. I shall only speak of some particular ones; and now, since we are at the column of the vertebræ, that is, the spine, let us not leave it till we thoroughly comprehend the utility of its construction. The spinal marrow, which is lodged in the cavity of the vertebræ, is of the same substance as the brain; it is this that supplies almost every part of the body with nerves. It is, therefore, of the highest importance, that, like the brain, it should be protected against external accidents.

To this end, it was necessary that it should be enclosed in a bony case. But this purpose might have been answered by a bone like that of the leg. This bone would have enclosed and protected the spinal marrow: don't you think it would?

*Alfred.* Yes, papa.

*Mr. Vermont.* But then the body would have been immoveable, and it would have been impossible for us to stoop, or to bend in any way whatever.

*Richard.* But it might have had joints like those of the elbow and knee.

*Mr. Vermont.* But then there would have been other inconveniences. In the first place, the parts of the canal of the vertebræ, forming very small angles, or approaching very near to each other, the spinal marrow would have been compressed in the concavity of the joint; and it would have been broken, or at least too much stretched in the convexity. Secondly, supposing these inconveniences had not occurred, and the body had been capable of bending backward and forward, still it could not have leaned to one side, as is apparent in the articulations of the knee, the elbow, and the fingers.

*Richard.* That is very true.

*Mr. Vermont.* To render the body flexible in every direction, and yet keep the marrow from being compressed, it was not possible to give the spine a more appropriate structure than what it has*. It was highly important to protect the spinal marrow, and to prevent acute angles, which would infallibly have bruised it.

To this end, it was necessary that the vertebræ should be very small, and consequently very numerous. Besides, as the spine was not designed to form an angle, but a curve when it moved, Nature has admirably adapted it to that end. Each vertebra is articulated with two others, by means of a cartilage, subservient to various purposes of very great necessity.

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* "The structure of the spine," says Dr. Kiel in his Anatomy, "is the very best that can be contrived; for, had it been all one bone, we could have had no motion in our backs; had it been of two or three bones articulated for motion, the medulla spinalis must have been necessarily bruised at every angle or joint; besides the whole would not have been so pliable for the several postures we have occasion to put ourselves in. If it had been made of several bones without intervening cartilages, we should have had no more use of it than if it had but one bone. If each vertebræ had had its own distinct cartilages, it might have been easily dislocated. And lastly, the oblique processes of each superior and inferior vertebra keep the middle one that it can neither be thrust backwards nor forwards to compress the medulla spinalis."

In the first place, the cartilage prevents the vertebræ from receiving injury by rubbing against each other.

Secondly, when we bend the spine toward the right side, for instance, the vertebræ approach nearer to each other on that side, and must necessarily be wider apart on the left. Without the cartilage, which possesses the property of yielding and shrinking, this could never be the case: for at the time when the spine bends towards the right, the cartilage, being pressed by the vertebræ, becomes thin on that side, and allows the vertebræ to approach each other; but on the left it contracts at the same time in proportion, and becomes thicker.

Thirdly, a point particularly necessary here is, that the cartilage should likewise possess elasticity, or the property of stretching, that, after it has been compressed, it may return to its former state, and that after being stretched it may again contract. This elastic cartilage, placed by Nature between the vertebræ, serves not only to render the bending of the spine more easy and convenient, but likewise by its very elasticity, to restore it after inflexion to its natural state. The greatest mathematicians, after examining this arrangement with the utmost nicety, have been obliged to acknowledge that nothing can be more admirable*.

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* The spine was not only designed to furnish a convenient medium for bending the body in any direction, and as the main trunk for the passage from the brain of the medullary substance—in which points of view alone it is here considered. It has also to give out from that substance, in its progress, small pipes, or nerves, which distribute this essential supply to every part of the body. The same spine has to serve another purpose not less necessary, to afford a stay or basis, or more properly speaking, a series of them, for the insertion of the muscles which are spread over the trunk of the body; in which trunk there are not, as in the limbs, cylindrical

Were I not afraid of tiring your attention with terms too scientific, I should, on occasion of the bones, say something of

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bones to which they can be fastened; and likewise, to furnish a support for the ends of the ribs to rest upon. The manner in which these different purposes are effected is admirably illustrated by the ingenious Paley.

"For the medullary canal giving out in its course and in a convenient order a supply of nerves to different parts of the body, notches are made in the upper and lower edge of every vertebra, two on each edge, equidistant on each side from the middle line of the back. When the vertebræ are put together, these notches exactly fitting, form small holes, through which the nerves, at each articulation issue out in pairs, in order to send their branches to every part of the body, and with an equal bounty to both sides of the body. For the next purpose, that is, the insertion of the bases of the muscles and the support of the ends of the ribs, especially the former part of it, a figure specifically suited to the design, and unnecessary for the other purposes, is given to the constituent bones. Whilst they are plain, and round, and smooth, towards the front, where any roughness or projection might have wounded the adjacent viscera, they run out behind and on each side into long processes, to which the muscles necessary to the motions of the trunk are fixed, and with such art, that whilst the vertebræ supply a basis for the musthe periosteum, the ligaments, and the synovial glands.

*Richard.* Papa, pray give us an expla-

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cles, the muscles help to keep these bones in their position, or by their tendons to tie them together.

"That most important and general property, the strength of the compages, and the security against luxation, was however to be still more specially consulted; for where so many joints were concerned, and where in every one derangement would have been fatal, it became a subject of studious precaution. For this purpose, the vertebræ are articulated, that is, the moveable joints between them are formed by means of those projections of their substance, which we have mentioned under the name of processes; and these so lock in with and overwrap one another, as to secure the body of the vertebra, not only from accidentally slipping, but even from being pushed out of its place by any violence short of that which would break the bone. I have often remarked and admired this structure in the chine of a hare. In this, as in many instances, a plain observer of the animal economy may spare himself the disgust of being present at human dissections, and yet learn enough for his information and satisfaction, by even examining the bones of the animals which come upon his table. Let him take, for example, into his hands a piece of the clean-picked bone of a hare's back; consisting we will suppose of three vertebræ.

nation of those terms. I will listen very attentively, in order to comprehend their signification.

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He will find the middle bone of the three so implicated, by means of its projections or processes, with the bone on each side of it, that no pressure which he can use will force it out of its place between them. It will give way neither forward, nor backward, nor on either side. In whichever direction he pushes, he perceives in the form, or junction, or overlapping of the bones, an impediment imposed to his attempt; a check and guard against dislocation. In one part of the spine he will find a still further fortifying expedient, in the mode according to which the ribs are annexed to the spine. Each rib rests upon two vertebræ. That is the thing to be remarked, and any one may remark it in carving a neck of mutton. The manner of it is this: the end of the rib is divided by a middle ridge into two surfaces, which surfaces are joined to the bodies of the two contiguous vertebræ, the ridge applying itself to the intervening cartilage. Now this is the very contrivance which is employed in the famous iron bridge at my door at Bishop-Wearmouth, and for the same purpose of stability, viz. the cheeks of the bars which pass between the arches, ride across the joints, by which the pieces composing each arch are united. Each cross-bar rests upon two of these pieces at their place of junction, and by that position, resists, *Mr. Vermont.* The periosteum is a membrane of a very close texture, which covers the whole surface of the bones except in places to which ligaments and tendons are attached, and where they are provided with cartilages. That part of the teeth, which is above their sockets, likewise has no periosteum. The uses of this membrane are, to unite the bones to the other parts, and to convey to them the small blood-vessels which penetrate and nourish them.

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at least in one direction, any tendency in either piece to slip out of its place. Thus perfectly, by one means or the other, is the danger of slipping laterally, or of being drawn aside out of the line of the back, provided against; and to withstand the bones being pulled asunder longitudinally, or in the direction of that line, a strong membrane runs from one end of the chain to the other, sufficient to resist any force which is ever likely to act in the direction of the back, or parallel to it, and consequently to secure the whole combination in their places. The general result is, that not only the motions of the human body necessary for the ordinary offices of life are performed with safety, but that it is an accident hardly ever heard of, that even the gesticulations of a harlequin distort his spine."

The ligaments are strong, fibrous, compact substances, difficult to be broken and torn, and which serve to attach several parts to each other.

Synovia is an unctuous and mucilaginous liquor, which is found within the joints, and is destined to keep the ligaments supple, and to moisten the surfaces of their cartilages, that they may slide with more facility over one another. It is pressed out by small glands, situated close to the joints*.

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* The joints display equal, if not still more striking marks of skill and contrivance than the bones themselves. In all joints, the ends of the bones which work against each other are tipped with gristle, the smooth surface and unfriable nature of which render it of all substances the most proper for that place. Bones are joined either moveably or immoveably. The moveable joints are formed in three ways: by a ball and socket, which admits of motion in all directions, as at the shoulder; by a hinge, which allows motion in only two directions, as at the knee; and by a long process of one bone received into the cavity of another, which admits of a rotatory motion, as in the articulation of the first and second vertebræ of the neck. The immoveable articulation of bones is of two kinds: first, where nu-

*Richard.* I should like to know, papa, how bones are made in the inside.

*Mr. Vermont.* The inside of bones is as

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merous processes of two bones, like the teeth of saws, are mutually received into each other, as in the bones of the head; and secondly, by the growing together of bones with the intervention of cartilage, as in the union of the os sacrum with the ossa innominata.

"In considering the joints," says Paley in his concluding observations on this subject, "there is nothing perhaps which ought to move our gratitude more than the reflection, how well they wear. A limb shall swing upon its hinge, or play in its socket, many hundred times in an hour, for sixty years together, without any diminution of its agility!—Moveable joints I think compose the curiosity of bones: but their union, even where no motion is intended or wanted, carries marks of mechanism and of mechanical wisdom. The teeth, especially the front teeth, are one bone fixed into another, like a peg driven into a board. The sutures of the skull are like the edges of two saws clapped together, in such a manner that the teeth of one enter the intervals of another. We have sometimes one bone lapping over another and planed down at the edges; sometimes also the thin lamella of one bone received into a narrow furrow of another: in all which varieties we seem to discover the same design, firmness of juncture without clumsiness in the seam."

remarkable as their outside. Within are discovered three kinds of substances, and cavities of different sizes, which contain the marrow and the blood-vessels. Of the three substances of bones, one is compact to give them the requisite solidity; another is cellular, to render them lighter with the same bulk; and this is harder in those which have to support considerable efforts, and of a lighter and more spongy texture in the others. The third is reticular, or more or less resembles a kind of net-work. It serves to support the marrow, and keeps it from sinking down.

*Richard.* What is the use of the marrow in the bones, papa?

*Mr. Vermont.* The principal use of the marrow is to keep the bony fibres in a state of suppleness which prevents them from breaking.

*Eliza.* Pray, papa, leave the inside of the bones, and tell us something about the face.

*Mr Vermont.* Before I say any thing concerning the face, I ought to give you some idea of the construction of the head in general, which is still more astonishing than that of the rest of the body. The architect seems to have exerted his utmost skill to crown his work. What a number of bones are collected to form the dome! Sixty-eight have been distinctly counted.

*Alfred.* I should never have supposed that my head contained so many bones.

*Eliza.* I thought that mine was formed of one single piece.

*Mr. Vermont.* This is a proof that all the bones which compose it are wonderfully arranged.

*Richard.* They must indeed be joined together with great skill, never to be deranged. But, papa, since, as you tell us, the author of Nature does nothing in vain, all these bones of which you speak must be designed for some particular use.

*Mr. Vermont.* Certainly; and if I were not afraid of being too prolix, I would explain to you the use of all the parts of the head. You would soon perceive that there is not one of them but what is necessary not only for our convenience, but even for our existence.

*Eliza.* Come then, papa, and sit down on the grass.

*Alfred.* It is lucky, papa, that the sixty-eight bones of the head are not visible; without the skin which covers them what frights we should be!

*Eliza.* Indeed we should.

*Mr. Vermont.* The human skeleton, I must own, however charming it may appear in the eyes of some people, exhibits a very disagreeable spectacle to others. Let us then consider it clothed with its natural coverings; and leaving the inside of the head, let us speak only of the outside. Let us admire the exact symmetry observed in all the features of the face. The face is an open book, in which people may every moment read what is passing in our minds. The rich colours with which Nature has embellished the face, alternately express either the tranquillity of the soul by their serenity, or its secret workings, by their sudden alteration.

Over the cheeks, lips, and the whole face, are distributed an inconceivable number of small muscles, which are susceptible of as many different expressions as motions. Some raise our eye-lids, enlarge the aperture of the eyes, and give us an air of haughtiness or indignation; others lower the eye-lids so as to conceal the eyes, and, by the multitude of wrinkles formed in the lower part of the forehead, denote either grief or profound meditation.

*Alfred.* Papa, are the faces of children as expressive as those of grown-up people?

*Mr. Vermont.* Very often more expressive, because they are more ignorant of the art of dissimulation. That candor and simplicity depicted in their faces, render them the more interesting, as they denote the innocence of their hearts. Look at a child asleep. What sweet serenity! Its cheeks and lips have the color of the rose; from time to time, pleasing dreams imprint a smile on its lips. In this infant, wrapped in peaceful slumbers, we discover that, of all the forms in Nature, none is more beautiful, more touching, more expressive than the human face.

*Eliza.* It is very extraordinary, that though all faces are made in the same manner, there are no two exactly alike.

*Mr. Vermont.* The reason why this should be the case is so plain, that I need not repeat it: but, my dears, it is remarkable that there is no part of the face but what is useful, and at the same time adds to its beauty. Let us take the lips for example: they are indispensably necessary. First, they open to receive food; then they close to prevent its dropping out of the mouth. They keep it in when the teeth open, and also prevent the saliva from running out continually.

*Eliza.* That would be a disgusting sight!

*Mr. Vermont.* In grown-up people, they form the voice; in children they serve for sucking.

*Alfred.* Indeed the utility of the lips is plain enough.

*Mr. Vermont.* Let us now examine their

form and expression. We shall find that the upper is cut somewhat in the shape of a heart, and the lower is suitably rounded. They have a language often more expressive than words, and long anterior to the latter; for before an infant can articulate any sound, he shews by the expression of his lips what is passing in his soul. They are the seat of the sweet smile, and likewise of repulsive disdain; and to confine ourselves to the laugh, of which the lips are the organs, you know how many kinds there are, such as the horse-laugh, the forced laugh, the graceful, disdainful, serene, hypocritical, spiteful, silly, sarcastic, &c. You see from this enumeration, how great must be the flexibility of the lips, to adapt themselves to motions so contrary and diversified.

*Alfred.* Indeed this flexibility appears surprizing.

*Mr. Vermont.* It is nothing in comparison of that of the tongue, which is a prodigious assemblage of different muscles;

It can instantaneously, and without any other preparation than the order or intention of the person to whom it belongs, render itself longer or shorter, sharper or flatter, swell, turn, bend, touch either the palate or the top or bottom of the teeth, and perform movements with astonishing celerity.

*Eliza.* You mentioned the teeth just now, papa. I think they perfectly justify what you said a little while ago. They are very useful to us, and also serve to adorn the face.

*Alfred.* How many teeth have we? I never counted them.

*Mr. Vermont.* Grown-up people have thirty-two, but children of your age no more than twenty six or twenty-eight.

*Alfred.* What are the teeth made of, papa?

*Mr. Vermont.* The teeth are so many small bones surrounded with a very hard enamel. This enamel, or varnish, resembling ivory, which the teeth cannot be deprived of, without decaying, is composed of parallel fibres or vessels which cover a matter so extremely hard, that some have considered the teeth as a petrified substance. You must have observed, that all the teeth are not alike. Some are called incisive; these stand in the front. They are flat bones, sharp at the end, placed one beside another, and forming an arc of a circle. The canine teeth follow to the right and left of the incisive; they are rounded and more pointed, that they may penetrate with the greater ease into aliments that are fibrous and capable of resistance. Lastly, come the *molares* or grinders, so called from their action; they have a square surface, which gradually increases the farther back they stand.

*Alfred.* Is it necessary then, papa, that we should have several kinds of teeth?

*Mr. Vermont.* Certainly, my dear. As Nature has designed us to feed both on the fruits of the earth, and the flesh of animals, it was necessary that she should give us at one and the same time incisive teeth, canine teeth, and grinders. Each species of animal is confined to one kind of food; but man, as soon as he acquires teeth, accommodates himself to every thing. This you know, my dears, and you are certainly glad that you have incisive teeth, when any one gives you a peach or a slice of melon; canine teeth, when you are going to make a solid meal; and grinders when you want to crack a nut.

*Richard.* We cannot too often repeat, that the Author of Nature has done all things well*.

*Mr. Vermont.* Indeed he has; but in

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* The more minutely the mechanism of the human body is investigated, the greater admiration it will excite. Without previous information, who would have suspected the wonderful contrivance which the Creator has manifested in the structure of the tooth! Through a small hole in the root of every tooth we trace an artery to feed the bone, as well as a vein to bring back the spare blood from it; and yet both these, with the addition of the nerve which accompanies them, form a thread very little thicker than a horse hair.

studying his works, be not satisfied with indulging a sterile admiration; strive to deduce from it useful conclusions. The maker of a watch is acquainted with all the hidden springs which set it in motion. Hence you may conclude, that he who constructed the head, and has been pleased to endow it with a portion of intelligence, cannot be ignorant of what is passing there every moment. And how can the Supreme Workman, who formed the eye, be blind to our conduct? How can he, from whom we received memory, be deficient in that attribute in regard to our actions? In vain do we think to escape his eye; he knows all the thoughts of our minds, all the movements of our hearts; and to him our souls are exposed without the least disguise.

## *Explanation of Plate II.*

This plate represents a front view of the human skeleton, with some of the ligaments and cartilages which connect the bones to each other. The names given to the different bones which compose it are as follow:

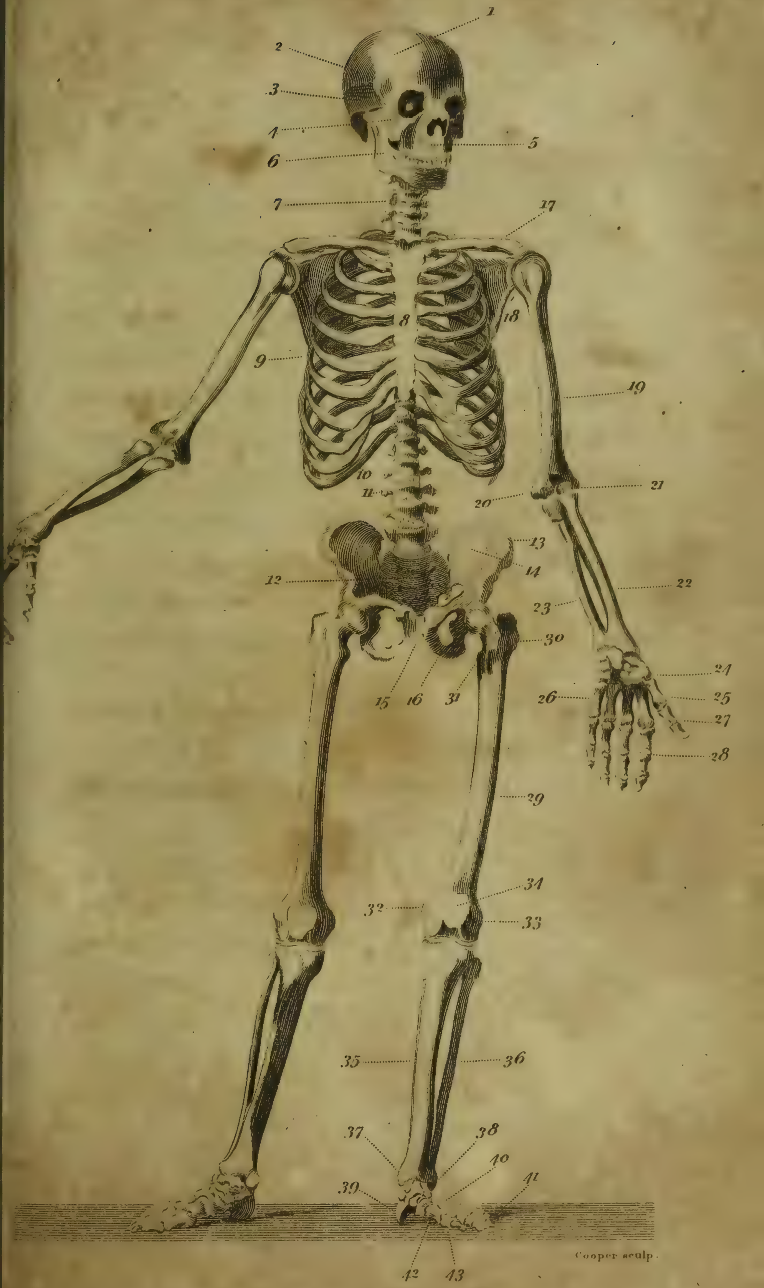
### *Bones of the Head and Neck*

1. Os frontis.
2. Os parietale.

   Between 1 and 2 part of the coronal suture.
3. The pars squamosa of the temporal bone.

   Between 2 and 3 the squamous suture. Below the pars squamosa, the zygoma; and lower down above 6, the mastoid process.
4. Os malæ. Above it a portion of the transverse suture.
5. Os maxillare superius, with the

*Plate II.*



Cooper sculp.

*Published April 2,1810, by R.Phillips, Bridge Street Blackfriars London.*

eight teeth of the right side.—The nasal process of the superior maxillary bone has the os nasi joined by the lateral nasal suture to its inside, and at the outside, within the orbit, the os unguis.

The ossa nasi joined to each other before by the anterior nasal suture.

6. Os maxillare inferius with 16 teeth; the four anterior named *incisores*, the two corner ones *canini*, and the five posterior on each side *molares*.

Opposite to 6, the angle of the lower jaw; above 6 the condyloid process, by which the jaw is connected to the temporal bone, at the root of the zygoma; and behind the os malæ, the coronoid process.

7. The seven cervical vertebræ with their intermediate cartilages.

Opposite to 7, their transverse processes.

### *Bones of the Trunk.*

8. Sternum.

8. Its middle piece, to which one half of the cartilage that connects the second rib, the whole of the cartilages of the third, fourth, fifth, sixth, and one half of the seventh are fixed.

Above 8, the first or upper triangular piece, to which the clavicle and one half of the cartilage that connects the second rib are fixed.

Below 8, the extremity or third piece of the sternum, named the cartilago ensiformis, to which one half of the cartilage that connects the seventh rib is fixed.

9. The seventh or last true rib.

10. The twelfth or last of the five false ribs.

11. The five lumbar vertebræ, with their intermediate cartilages.

Opposite to 11 their transverse processes.

12. The os sacrum with its five divisions.

13. Os innominatum, divided into

14. Os ilium.
15. Os pubis.
16. Os ischium
Opposite to 16 the foramen thyroideum.

*Bones of the Superior Extremity.*

17. The clavicle fixed before to the first piece of the sternum and outwards to the acromion of the scapula.
18. The scapula.
Above 18 the cervix of the scapula. Opposite to it, the inferior costa; and below the outward extremity of the clavicle are seen the superior costa and coracoid process.
19. The os humeri. The upper end of it which is connected to the cavity of the scapula, named the *glenoid,* below the acromion, is denominated its *head* or *ball;* on each side of which are seen the tubercles, named the *internal* and *external;* and between these a groove for lodging the biceps flexor cubiti.

20. The internal condyl.

21. The external condyl.

Between 20 and 21, the trochlea, upon which the ulna moves.

22. The radius. The upper end, which moves on the external condyl of the os humeri, is named its *head*; below that, the tubercle for the insertion of the biceps flexor cubiti, and between these the cervix. The inferior end of it is connected to the carpus.

23. The ulna. The upper end of it forms the coronoid process, for the insertion of the brachialis muscle. The inferior end has a process named the *styloid*, which is connected to the carpus by a ligament.

24. The carpus, formed of eight bones.

25. Metacarpal bone of the thumb.

26. The metacarpal bones of the four fingers.

27. The two joints of the thumb.

28. The three joints or phalanges of the fore-finger; and the same are seen in each of the other three.

### *Bones of the Inferior Extremity.*

29. The os femoris. The upper end of it is named its *head* or *ball,* which is lodged in a deep socket of the os innominatum, named the *acetabŭlum.* Between the head and trochanter major, the cervix.
30. Trochanter major.
31. Trochanter minor.
32. Internal condyl.
33. External condyl.
34. Patella. The place where it moves upon the os femoris, is named the *trochlea.*
35. Tibia. Between the tibia and the condyls of the os femoris, are seen the semi-lunar cartilages, and below the joint, the tubercle of the tibia.
36. Fibula.
37. Malleolus internus.
38. Malleolus externus.
39. Os calcis. Between 39 and 40, the other six bones of the tarsus.
40. Metatarsal bones of the four toes.

41. The three joints or phalanges of the four toes.
42. Metatarsal bone of the great toe.
43. The two joints of the great toe.

### *Explanation of Plate III.*

The figure in this plate exhibits a back view of the human skeleton, with some of the ligaments and cartilages which connect the bones.

### *Bones of the Head and Neck.*

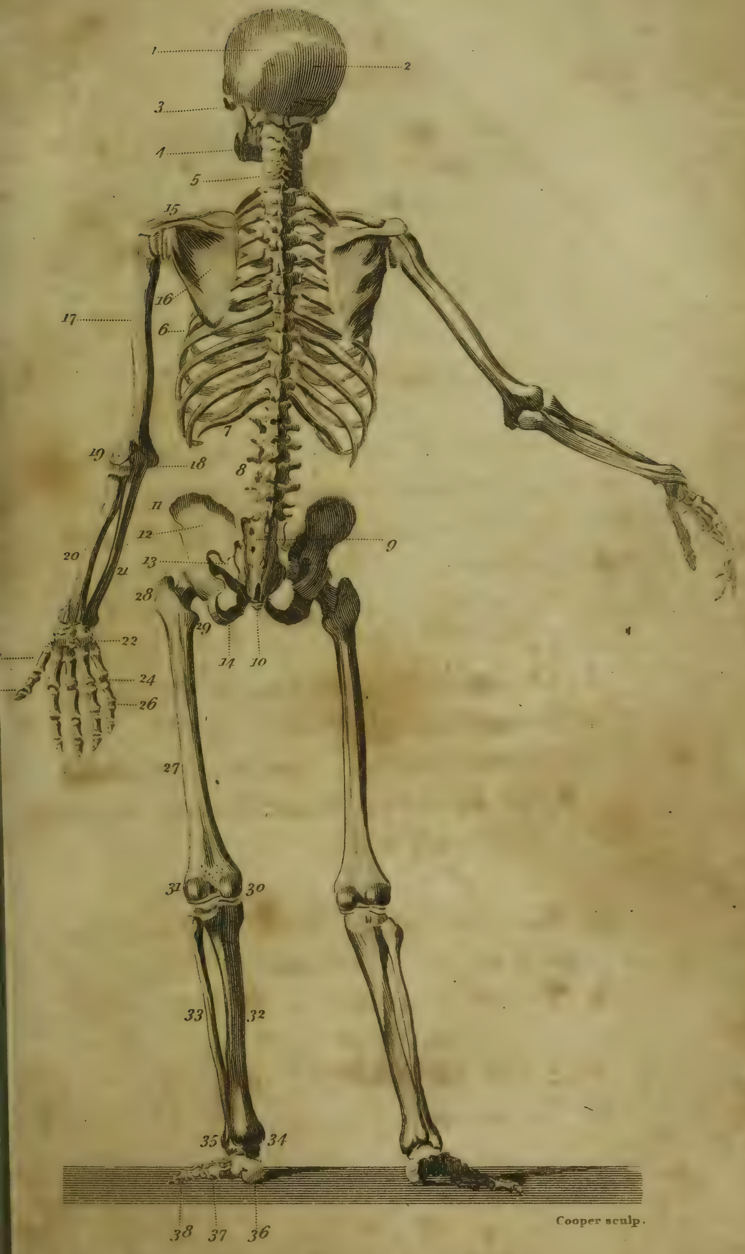
1. Os parietale, joined to its fellow by the sagittal suture.
2. The os occipitis joined to the parietal bones by the lambdoid suture, which is between 1 and 2.
3. Os malæ.
4. Maxilla inferior, with a view of the teeth of both jaws from behind.
5. The seven cervical vertebræ.

### *Bones of the Trunk.*

6. The seventh or last true rib.

# ANATOMY

*Plate III.*



Cooper sculp.

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7. The twelfth or last rib.
8. The five lumbar vertebræ.
9. Os sacrum.
10. Os coccygis.
11. Os innominatum, divided into
12. Os ilium.
13. Os pubis.
14. Os ischium.

*Bones of the Superior Extremity.*

15. The clavicle, joined outwards to the acromion of the scapula.
16. The scapula.
17. Os humeri.
18. Internal condyl.
19. External condyl.
20. Radius.
21. Ulna; its upper end named *olecranon;* and near the wrist its styloid process.
22. The eight bones of the carpus.
23. The metatarsal bone of the thumb.
24. The metatarsal bones of the four fingers.
25. The two joints of the thumb.

26. The three joints or phalanges of the four fingers.

*Bones of the Inferior Extremity.*

27. Os femoris.
28. Trochanter major, and at the inside of it, the cervix.
29. Trochanter minor.
30. Internal condyl.
31. External condyl.
32. Tibia.
33. Fibula.
34. Malleolus internus.
35. Malleolus externus.
36. The seven bones of the tarsus.
37. The metatarsus.
38. The joints or phalanges of the toes.

## SIXTH CONVERSATION.

### OF THE ARM AND HAND.

*Mr. Vermont.* I endeavoured yesterday to describe to you, my dears, the structure of the bones, and the wonderful skill with which they have been arranged, to support the body and facilitate all its motions. I shall to-day give you a new proof of the infinite wisdom of the Creator, in the construction of the human body, and the prodigious advantages which we derive from the arrangement of the various parts of which it is composed.

*Alfred.* What is this new proof, papa?

*Mr. Vermont.* You have it in your hand.

*Alfred (opening his hand).* I have it in my hand! What do you mean, papa?

*Eliza.* Oh! I guess. Papa means to

tell us something about the utility of the hand. Am I right?

*Mr. Vermont.* Yes, my dear. I commend your penetration. Did you ever reflect on the arrangement of your hands?

*Eliza.* Yes, papa; but you will certainly teach me a great deal concerning them that I am ignorant of.

*Alfred.* For my part, I never look at mine.

*Mr. Vermont (laughing).* That accounts for their being so often dirty.

*Alfred.* I plead guilty; but it proves at least that I would rather make use of my hands than look at them.

*Mr. Vermont.* Well said! But is it not unjust to be every minute making use of an instrument, to be daily deriving from it the most important and numerous advantages, without ever taking the trouble to examine the construction of that instrument?

*Alfred.* It is, I acknowledge.

*Mr. Vermont.* If we purchase a very useful machine which serves for a variety of purposes, which is equally remarkable for the durability and art of its construction, ought we not to admire the talents of the maker, and to bestow on him the praises which he deserves?

*Alfred.* Certainly.

*Mr. Vermont.* And if this invaluable machine be indispensably necessary, and the maker present it to us gratuitously, is not this an additional reason why we should pay this skilful and generous workman the tribute of admiration and gratitude, which the astonishing construction of his work and the value of his present alike demand?

*Alfred.* Undoubtedly; and he who, while using the gift, should forget to admire the skill, and to acknowledge the generosity, of his benefactor, would be the most ungrateful of men.

*Mr. Vermont.* My dear, there are many ungrateful beings among mankind.

*Eliza.* Thanks to you, papa, we shall not be among the number.

*Mr. Vermont.* Give me your hand, Richard, and Alfred. Give me yours, Eliza. O my children! how I wish that I could awaken in your hearts all the admiration and gratitude which I feel in my own, on beholding these hands, constructed with such consummate art, these hands which render you so many services, and without which existence would be a burden to you*!

*Alfred.* Why are not all the fingers of the same length, papa?

*Mr. Vermont.* The unequal length of the fingers, my dear, their arrangement, their figure, are all the work of the most profound wisdom. The human hand is so exquisitely constructed, that it is impossible to conceive how it could be altered for the better. In vain may the human understanding combine different forms; in vain may the imagination figure to itself different proportions, we should never be able to discover any better adapted to the purpose. By means of the pliancy and inequality of the fingers, we can grasp objects of every possible form. I see a ball yonder, at the skirt of the grove, close to a stone. Go, Alfred, bring the ball, and the stone too.

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* "And then our hands," exclaims Cicero, *(De Natura Deorum, lib. 2.)* "how convenient are they, and how useful in the arts! The fingers are extended or contracted without the least difficulty, so extremely flexible are their joints. With their assistance the hands use the pencil and the chisel; they play on the lyre and on the lute—so much for the agreeable. As to what is necessary, they cultivate the earth, build houses, manufacture stuffs, make clothes, and utensils of copper and of iron. The imagination invents, the senses examine, the hand executes. So that if we are lodged, clothed, and sheltered; if we have cities, walls, habitations, temples, it is to our hands that we are indebted for all these."

*Alfred (holding the ball in one hand, and the stone in the other).* Here they are, papa.

*Mr. Vermont.* The ball is a round body, and the stone an angular one; yet the hand grasps both of them with equal facility. Look at your fingers round the ball, which you support in the hollow of your hand; as they grasp the spherical body their inequality disappears. In this case you perceive the advantages of that very inequality. You must be aware that if the fingers were all of the same length when the hand is in its natural position, they would become very unequal in grasping a spherical body; which would render them infinitely less proper for the services which they are designed to render us.

*Alfred.* O papa! I see you are right. When my hand grasps the ball, I observe that all my fingers are of the same length, and that my thumb exactly corresponds with the middle finger.

*Eliza.* If our fingers did not bend, I should think they would be of no use to us.

*Mr. Vermont.* If the fingers were immoveably fixed one beside another, the hand of man would possess but a small portion of its present utility. If in this case the joints continued flexible, we might indeed grasp certain objects; but they would be of much less size than those which the expansion and pliability of our fingers enable us to lay hold of.

*Alfred.* I strive to keep my fingers close together, and I am convinced that if they were naturally placed so, the hand would be but an inconvenient instrument.

*Mr. Vermont.* Almost an useless one indeed; whereas in its present state it certainly is, according to the expression of a celebrated anatomist, "the organ of organs, and the instrument of instruments"

*Eliza.* It is, probably, because the hand is so useful an instrument, that we have received two.

*Mr. Vermont.* Undoubtedly;—and again, with a single hand we could have grasped only objects of inconsiderable dimensions. The assistance, therefore, which one hand affords the other, is a circumstance truly wonderful, since that assistance increases an hundredfold the utility which we derive from them.

*Alfred.* Why have we nails at the ends of our fingers, papa?

*Mr. Vermont.* The form of the human nails proves that they have not been given us for offensive weapons, like the claws of animals. Their utility is considerable.

They are placed in the most suitable manner; for had the nail surrounded the finger like a thimble, we should have lost that exquisite sensibility of touch, the chief seat of which is at the ends of the fingers*.

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* "When the epidermis," says Gregory in his *Economy of Nature*, "is removed from the true skin, we observe small obtuse papillæ, which seem to be the parts which more particularly receive the impressions of external objects. These papillæ are rather more remarkable in the skin at the ends of the fingers; and here we may perceive that they have nerves, though from the extreme minuteness of them, they are hardly observable. We judge of heat and cold from the object being hotter or colder than our fingers; of the weight of a body from its degree of pressure compared with its bulk; of its moisture by a peculiar sensation, which seems principally to arise from heat being quickly conveyed to or from the finger; of its figure by applying our hands to its different parts; of distance by comparison with what we know to be the length of the finger, hand, or arm."

St. Pierre observes, that touch, though the most obtuse of all our senses, is, in some measure, the seal of our intelligence. "To no purpose," continues he, "is an object exposed in every possible way to our view, we think our knowledge of it imperfect as long as we are not permitted to touch it. This sense, obscure as it on the opposite side to the nails. The nail serves to support the finger, and to

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is, may be made the channel of communicating intelligence, as is demonstrated by the example adduced by Chardin, of the blind Persians, who drew geometrical figures, and formed an accurate judgment of the goodness of a watch by handling the wheels."

These instances, however, have been far surpassed by natives of our own country, among whom may be mentioned Doctors Saunderson and Moyes, Mr. Stanley, John Metcalf, and the young lady who was attended by Sir Hans Sloane. The latter, in addition to the loss of sight, had also the misfortune to be deprived of hearing. In this melancholy situation her touch and smell became so exquisite; that she could distinguish the different colors of silk and flowers, and was sensible when any stranger was in the room with her. She worked much at her needle, and her work was uncommonly neat and exact. She used also to write; and her writing was yet more extraordinary than her needle-work: it was executed with the same regularity and exactness; the character was very pretty, the lines were all even, and the letters placed at equal distances from each other; but the most astonishing particular respecting her writing is, that she could by some means discover when a letter had by mistake been omitted, and would place it over that part of the word where it should have been inserted with a caret underneath it.

double its force upon occasion. Its substance has been selected with equal skill. Were it softer, it would not be adapted to the purposes which it now answers; and were it harder, it would be broken by the slightest effort of the last joint of the fingers.

*Richard.* What appears wonderful to me is, that the arm and hand are always ready to obey the will. If I chuse to open my hand, it opens immediately; if I chuse to shut it, it shuts with equal promptitude.

*Mr. Vermont.* Since we are speaking of the hand, we ought not to forget the arm, to which it is attached*. The human arm is an universal instrument. Its operations are so numerous, that it would be impossible to mention them all. In the first

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* "Another mechanical contrivance is seen in what anatomists call the fore-arm; that is, in the arm between the elbow and the wrist. Here, for the perfect use of the limb, two motions are wanted; a motion at the elbow backward and forward, which is called a reciprocal motion, and a rotatory motion, by which the palm of the hand, as occasion requires, may be turned upward. How is this managed? The fore-arm, it is well known, consists of two bones, lying alongside each other, but touching only towards the ends. One and only one of these bones is joined by the cubit, or upper

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part of the arm at the elbow; the other alone to the hand at the wrist. The first, by means, at the elbow, of a hinge joint, (which allows only of motion in the same plane) swings backward and forward, carrying along with it the other bone and the whole fore-arm. In the mean time, as often as there is occasion to turn the palm upward, that other bone to which the hand is attached, rolls upon the first by the help of a groove, or hollow near each end of one bone, to which is fitted a corresponding prominence in the other. If both bones had been joined to the cubit, or upper arm at the elbow, or both to the hand at the wrist, the thing could not have been done. The first was to be at liberty at one end, and the second at the other; by which means the two actions may be performed together. The great bone which carries the fore-arm, may be swinging upon the hinge at the elbow, at the very time that the lesser bone, which carries the hand, may be turning round it in the grooves. The management also of these grooves, or rather of the tubercles and grooves, is very observable. The two bones are called the radius and the ulna. Above, that is, towards the elbow, a tubercle of the radius plays into a socket of the ulna; whilst below, that is, towards the wrist, the radius finds the socket, and the ulna the tubercle. A single bone of the fore-place, this arm, when stiffened, performs the office of a lever or bar.

*Richard.* So it does; and that lever is very strong too.

*Mr. Vermont.* When bent in the different articulations which divide it, the arm resembles the flail, the bow, and all sorts of shapes.

*Richard.* By means of the fist at its end, it strikes like a mallet.

*Mr. Vermont.* The two arms when extended resemble the balance; and when one of them is shortened to support a weight, the other, by extending on the op-

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arm, with a ball and socket joint at the elbow, which admits of motion in all directions, might, in some degree, have answered the purpose of both moving the arm and turning the hand. But how much better it is accomplished by the present mechanism. Any person may convince himself, who puts the ease and quickness with which he can shake his hand at the wrist circularly, (moving likewise if he pleases, his arm at the elbow, at the same time) in competition with the comparatively slow and labouring motion with which his arm can be made to turn round at the shoulder, by the aid of a ball and socket joint."—*Paley's Natural Theology.*

posite side, maintains the equilibrium, and makes up, as in the Roman balance, for the excess of weight by the length of the lever. In truth, the arm is the model and the soul of every instrument. I say their soul, because the excellence of their effects invariably proceeds from the arm and hand, which direct them. It is their model, because they are all imitations and extensions of its different properties.

*Alfred.* I clearly perceive that papa is right; for by pressing my fingers together and giving them different positions, I can turn them into hooks, pincers, and tongs.

*Eliza.* And I can hollow out my hand into a kind of cup, which would serve to carry water in, or even to drink out of.

*Mr. Vermont.* Yes, my dears: cups, spoons, tongs, pincers, peels, spades, forks, mallets, levers, and all other implements, are so many hands which imitate on a larger scale what these perform on a smaller.

*Alfred.* Who would ever imagine, upon seeing a hand, that an instrument apparently so weak, could render us all the services that it actually does.

*Mr. Vermont.* Nothing, indeed, is more admirable. This arm, less than a yard long, and four or five inches thick, finds nothing that can resist it, when it is assisted by the force of the implements which represent it and facilitate its exertions. It then rives the solid rock, and perforates prodigious mountains; it sets bounds to the current of impetuous rivers, and conducts them into new channels. Iron and all other metals assume the form that it pleases to give them. It overcomes the resistance of stones and marbles; it moulds them like wax, either to make arches to join the opposite banks of a river, or bends them into a staircase, to give man access to every part of his house.

*Richard.* Or cuts them with the chisel, and raises them to a prodigious height, to construct a dome as beautiful as that of St. Paul's. But, papa, how can the hand venture to undertake such works?

*Mr. Vermont.* By calling in to its aid

levers, pullies, rollers, cranes, and all sorts of machines in which a very small force is sufficient to conquer a very great resistance. With this aid the human hand vanquishes all opposition; and it is this kind of magic power, by which it infallibly subjects to its will the most ponderous and intractable substances, that constitutes its chief glory.

*Alfred.* It must be confessed that man is under great obligations to his hands.

*Mr. Vermont.* Yes, my dear. Galen, an ancient author, who wrote a treatise on the use of the different parts of the human body, speaks of it nearly in these terms: "Man has not received hands for his defence alone; but with his hands he wields the lance and the sword, arms more formidable than the weapons of animals. He has not received pincers like insects, but in his hands, wood and iron serve him in their stead, and in a manner still more beneficial. The lion possesses superior agility; but with his hands man has tamed the horse, which surpasses the lion in swiftness.

Mounted on a spirited steed, man pursues that formidable animal, whom he overtakes and dispatches at his feet. No, it is not true that man is naked, defenceless, and easily wounded. His hands cover him, if he pleases, with a coat of mail, which is more capable of warding off injuries than the hardest hides of animals, and the triple scales of certain fishes; and it is not merely this armor that protects him, but a house, the ramparts of a town, the towers in which he entrenches himself. His hands served him to build those houses, to erect those towers. To his hand man is indebted for his clothing. With the assistance of that member he makes both the nets with which he catches the inhabitants of the air, and those in which he takes the tenants of the deep."

*Alfred.* It must, nevertheless, require a great deal of courage to seize such savage animals as the lion and tiger.

*Mr. Vermont.* Look at this hand.

*Alfred.* Yes, papa.

*Mr. Vermont.* It could not resist the

teeth of the tiger; an elephant would break it with one blow of his trunk; a leopard would make but one mouthful of it——

*Eliza.* True; but fortunately we are not in Africa.

*Mr. Vermont.* Well, and yet it is so weak an instrument that chains the leopard, the tiger, and the lion. 'Tis the hand of man that subdues the elephant and the rhinoceros. It tames the bear, who licks it like a dog, and binds the camel, who falls upon his knees to be tied, or to receive the burden which it prepares for him. Not only does it soften the ferocity of the most savage animals, but it reduces their very passions and violence to its service. Its dexterity turns every thing to advantage; and though this hand is of itself a very small affair, yet, when you survey all that it accomplishes, you would take it for a supernatural instrument.

*Eliza.* In treating of the fingers, papa, you forgot to speak of their pliability. If they were not extremely pliable, we could not learn either to play on the piano-forte or the harp.

*Mr. Vermont.* Very true, my dear; we should in that case have no concerts; and what would be a still greater misfortune, there would be no spinning or sewing.

*Alfred.* Is the art of spinning then so very necessary?

*Mr. Vermont.* 'Tis one of the most indispensable. It is an assemblage of threads, formed by the hands of women, that composes stuffs of every imaginable texture, from the thickest cable to the most transparent muslin. It is therefore this operation that clothes and supplies us with many conveniences.

*Alfred.* How silly I was to despise so useful an art! I now see that the hand which turns the spinning-wheel is as worthy of respect as that which erects an edifice, or launches a ship.

*Mr. Vermont.* Yes, my dears; those hands which hold the distaff and turn the wheel deserve the highest respect: they provide man with wings swifter than those of birds.

*Eliza.* Explain yourself, papa; I don't understand you. I always thought that birds alone had wings.

*Alfred.* Oh! that man had but wings too*!

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* "The art of flying," observes the pious Derham, "though in some cases it might be of good use, as to the geographer and philosopher; yet, in other respects, it might prove of dangerous and fatal consequence; as for instance, by putting it in man's power to discover the secrets of nations and families more than is consistent with the peace of the world for men to know; by giving ill men greater opportunities to do mischief, which it would not lie in the power of others to prevent; and as one observes, by making men less sociable: for upon every true or false ground of fear or discontent and other occasions, he would have been fluttering away to some other place; and mankind, instead of cohabiting in cities, would, like the eagle, have built their nests upon rocks."

Notwithstanding the great improvements made in art and science, since the publication of the work of the above-mentioned philosophic divine, his position still holds good in a great measure. Aerostation continues

*Mr. Vermont.* And has he not? What are the sails of ships woven by his hands, but wings which enable him to traverse the ocean, a privilege which even the soaring eagle does not enjoy?

*Alfred.* What prodigies the human hand accomplishes!

*Mr. Vermont.* Shall I tell you which is one of the most striking?

*Alfred and Eliza.* Yes, papa.

*Mr. Vermont.* You have heard all that I have said concerning the arm and hand, since the beginning of our conversation.

*Alfred and Eliza.* Yes, papa.

*Mr. Vermont.* The words which we have employed were the images of our ideas. When we spoke we painted what

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to be a subject of curiosity rather than utility. The recent success of M. Degen, a watchmaker of Vienna, in the art of flying, by means of an apparatus of his own invention, promises indeed to give man an increased facility of elevating himself into the air, but whether that power can ever be applied to any extensively useful purpose, appears extremely problematical.

the mind thought, and now I am going to avail myself of the method which is employed to paint words.

*Alfred.* But how can any body paint words? I know that a person, a tree, a house can be painted; but to paint words seems quite impossible.

*Mr. Vermont.* And yet you do it yourself every day of your life.

*Alfred.* Indeed!

*Mr. Vermont.* Yes, my dear, and by means of your fingers. People paint their thoughts by words and their words by writing.

*Eliza.* Now I comprehend you perfectly well.

*Mr. Vermont.* As you can draw several portraits of the same person, so you may make several copies of the same conversation.

*Richard.* Certainly. If each of us were to write it down, we should then have three different copies.

*Mr. Vermont.* How wonderful that the hand can write what the lips utter! But this is not all. When you have written down our conversation, and I have made such corrections as appear necessary, I shall send it to a printer, a friend of mine, who in a short time will make all England and even foreign countries acquainted with it. People at the distance of thousands of miles will know all that I have said to you, as well as your answers. The panegyric on the hand and arm will be read at London, Paris, New York, and in many retired country-houses, where affectionate parents superintend the education of their beloved children as I do yours.

*Richard.* It must be confessed that the hand is an universal instrument.

*Mr. Vermont.* Yes, my dear: and if it were possible to enumerate all the services which it is capable of rendering us, they would excite inexpressible astonishment. There are many occasions, for instance, on which the hand speaks, sees, and hears: so that in case of necessity it can serve instead of tongue, eyes, and ears.

*Eliza.* How so? I can scarcely conceive that.

*Mr. Vermont.* What! if you were to lose the faculty of speech——

*Eliza.* Ah! I guess what you mean. The dumb speak by means of signs, and it is with the hands that those signs are made. I am now convinced that there are cases in which the hands can speak.

*Mr. Vermont.* The fingers are so flexible, that all the letters of the alphabet may be represented with them.

*Richard.* Yes, I know they can. I have seen little children conversing together in this manner with the greatest fluency.

*Mr. Vermont.* It is not the dumb only that employ the language of the hand to convey their sentiments to each other. There are persons who speak perfectly well, and yet disdain not sometimes to employ it.

*Eliza.* I remember that one day when you had company to dinner, I was pressed very much to sing a song. I refused at first partly from self-will, and partly from timidity; but one of your looks (for it appears that the eyes can speak too) encouraged me to such a degree that I ventured to comply. When I had done, all the company paid me high compliments; but as you have taught me that compliments are not always perfectly sincere, I made little account of them, when all at once I found you by my side. You took my hand and pressed it in yours without speaking a single word. I must however confess, that my heart instantly understood this kind of approbation, and that this compliment was infinitely more agreeable to me than all the others.

*Alfred.* On what occasions, papa, may the hands serve instead of eyes?

*Mr. Vermont.* Whenever we are in the dark, my dear, we have our eyes at our finger's ends. This you must well know from experience.

*Alfred.* Indeed I do. When we go into

a dark room, we stand in absolute need of the assistance of our hands, that we may not break our heads.

*Eliza.* You must, however, admit, papa, that these eyes are not so serviceable as the others.

*Mr. Vermont.* That I readily acknowledge.

*Eliza.* People born blind are greatly to be pitied.

*Mr. Vermont.* Certainly: their situation is melancholy, but in their misfortune they are happy in being able to discover what surrounds them by means of their hands. The hands of the blind are infinitely more expert than ours. Means have been found to instruct them as well as if they possessed the faculty of sight. There are now people born blind who read perfectly well, write, print, learn geography, and other sciences.

*Alfred.* But papa, is it possible for people born blind, to learn to read? That appears so wonderful that I can scarcely believe it.

*Mr. Vermont.* Yet nothing can be more true. By means of letters, characters and maps in relievo the blind learn by the touch to study their configuration and to distinguish between them; and in time habit enables them to read as quickly with their fingers, as you can with your eyes.

*Eliza.* What do you mean, papa, by letters in relievo?

*Mr. Vermont.* Here, Eliza, is a sealed letter which I forgot this morning to send to the post. Do you see the impression made by my seal upon the wax?

*Eliza.* Yes, papa.

*Mr. Vermont.* Well, that V is a letter in relievo: and by touching it you would know what it was without looking at it.

*Eliza.* I should indeed. I now conceive in what manner the blind are instructed.

*Mr. Vermont.* Let us here, my dears, conclude a conversation, which might be continued to a much greater length. Night approaches and the dew begins to fall; it is time to return home.

## SEVENTH CONVERSATION.

### OF RESPIRATION, THE CIRCULATION OF THE BLOOD, THE MUSCLES, AND THE NERVES.

Mr. Vermont's children were highly pleased with the conversation on the hand. The next day they earnestly begged for a new walk: and no sooner had they received the signal for their departure than they joyfully quitted the house, ran together to the meadow and then returned to meet their father. "Oh dear!" cried Eliza, "I can't run any more, I am quite out of breath—Richard and Alfred—"

*Mr. Vermont.* Why did you go with them?

*Eliza.* I couldn't help it—they took hold of me—one on either side—and dragged me along with them—so that now I can scarcely breathe.

*Richard.* As you are so well acquainted with the human body, papa, give us some account of breathing.

*Mr. Vermont.* Breathing, or respiration, according to the complete signification of the term, consists of two contrary actions, one called *inspiration,* by which we draw in the external air, and *expiration,* by which we again expel it. Such is the life of man, from the moment of his birth till his death. Life commences with inspiration, it concludes with expiration, and is kept up by both.

*Richard.* The air then is absolutely necessary for life.

*Mr. Vermont.* Certainly. Without air we could not breathe, and without breathing it would be impossible to live. It is necessary besides, that the air should be sufficiently pure; neither too thick nor too light. The author of life, when he constructed the human body, must consequently have calculated the quality of the air which we were to breathe; and when he created the air, he must also have thought of the beings that were to exist in that element—a convincing proof that the universe is not the work of chance!

*Richard.* Just in the same way as the eye was adapted to the light and the light to the eye.

*Mr. Vermont.* Yes, my dear; and we find the same wisdom displayed in the construction of the organs of respiration. It is necessary that the external air should enter our lungs; for this purpose a pipe has been hollowed out for it, resembling the body of a pump, which, at its entrance into the lungs, is divided into an infinite multitude of little channels, called *bronchiæ,* in order to convey it to the lungs. It is necessary that neither this canal, nor any of its divisions should ever be entirely choked up; which would alone be sufficient to extinguish life. They are therefore formed of a substance so solid, that these tubes are kept continually open by their own consistence. But how can the external air enter a pipe which is already full of it? To this question I answer, that, the external air being denser, or thicker than the internal, which is warmer, it must, by the laws of nature, find less resistance in that quarter, and consequently force a passage. But where will it go to? The lungs and the heart already occupy the whole cavity of the chest. True; but nature has formed the lungs of a soft and spongy substance, to admit the air, which swells them up as water does a sponge*. In inspiration†, the ribs by which the lungs are inclosed rise a little to leave them room to expand*. In expiration, the lungs pressed by the sides, which then contract, expel the air from their cells, after it has there performed its first function, namely, to keep them constantly cool—a necessary precaution to prevent the vicinity of the heart, which is a kind of furnace, from heating them, or even producing dangerous inflammations.

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* From the extreme minuteness of the vesicles or air-vessels of the lungs, it has been computed that the external surface of the latter is not less extensive than the floor of a moderate sized sitting room.

† One inspiration is commonly performed for every four or five pulsations of the heart; and the latter in different healthy persons, vary from 60 to 90 times in a minute. From some experiments made by Dr. Goodwyn, he concludes that the lungs contain 109 cubic inches of air, after a complete expiration, and that this quantity receives an addition of 14 cubic inches by inspiration. The dilatation of the lungs, therefore, after expiration, is to their dilatation after inspiration as 109 to 123.

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* "The reciprocal enlargement and contraction of the chest to allow for the play of the lungs, depends upon a simple yet beautiful mechanical contrivance, referable to the structure of the bones which inclose it. The ribs are articulated to the back-bone, or rather to its side projections, obliquely: that is, in their natural position they bend or slope from the place of articulation downwards. But the basis upon which they rest at this end being fixed, the consequence of the obliquity or the inclination downwards is, that, when they come to move, whatever pulls the ribs upwards, necessarily at the same time draws them out; and that while the ribs are brought to a right angle with the spine behind, the sternum or part of the chest to which they are attached in front, is thrust forward. The simple action therefore, of the elevating muscles does the business; whereas if the ribs had been articulated with the bodies of the vertebræ at right angles, the cavity of the thorax could never have been further enlarged by a change of their position. If each rib had been a rigid bone, articulated at both ends to fixed bases, the whole chest had been immoveable. Keil has observed that the breast-bone, in an easy inspiration is thrust out one-tenth of an inch; and he calculates that this, added to what is gained to the space within the chest, by the flattening or descent of the diaphragm,

*Richard.* Has the air any other functions to perform in the human body?

*Mr. Vermont.* Undoubtedly; but it would lead us from our present subject

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leaves room for forty-two cubic inches of air to enter at every drawing in of the breath. When there is a necessity for a deeper and more laborious inspiration, the enlargement of the capacity of the chest may be so increased by effort, as that the lungs may be distended with seventy or a hundred such cubic inches. The thorax, says Schelhammer, forms a kind of bellows, such as never have been and probably never will be made by any artificer." *(Paley's Natural Theology).*

It may be observed that there is a considerable difference between the calculations in this and the preceding note, respecting the quantity of air inhaled at one inspiration. This is one of those points in the economy of animal life which will perhaps never be correctly ascertained.

were we to enter into a consideration of them. There are naturalists who think that small air-bubbles, by mixing and circulating with the blood, serve to render it more fluid and to accelerate its motion*.

*Richard.* You have not yet said any thing about the blood, papa. How is it formed? Where does it come from? Where is its source?

*Mr. Vermont.* In the heart! 'Tis there that the blood is prepared; thence it issues, and thither it is continually returning, after it has circulated with incredible rapidity through every part of the human body.

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* On the membranes of the air-vessels of the lungs are distributed the minute and very numerous ramifications of the pulmonary artery; and through the membranes, the air, without coming into direct contact with the blood, produces certain changes on it, which are found to be absolutely necessary for the continuance of life. One of the most obvious is the change of color; in the lungs it acquires a florid hue, which is gradually lost while the blood passes through the other parts of the body. To effect these changes and to produce animal heat, are, as far as we know, the chief uses of respiration.

*Richard.* I have heard of arteries and veins. Do those two words signify the same thing?

*Mr. Vermont.* The arteries convey the blood to every part of the body, and the veins carry it back to the heart, whence it again issues in order to return thither by a continual circulation. Imagine the heart to be a spring of blood, whence issue four large rivers conducted through the same number of pipes. These four rivers, all of which rise at the lower extremity of the heart, are the two great arteries, and the two great veins, both of which branch off into an infinite multitude of smaller streams; that no part of the body may be left without nourishment. The artery and the vein distinguished by the epithet *pulmonary* go no farther than the breast; they throw out their branches into the lungs alone: but the *aorta* or great artery, and the *vena cava,* send off their branches to all parts of the body, as well the most distant as the nearest to the heart. *(See pl.* 4 and 5*).*

*Richard.* Then the branches of the arteries and veins must be extremely numerous.

*Mr. Vermont.* Yes, my dear, innumerable. The aórta and vēna cava issue separately from the heart; the former from the cavity called its left ventricle, and the latter from the right ventricle. Who would suppose from their taking such different directions, that they are designed to meet again? Scarcely, however, have they quitted the heart, when they divide into several branches, which are again subdivided into others that shoot out in every imaginable direction, into superior or ascending, into collateral, direct, and oblique; and into inferior or descending; after which they all at once approach each other, the branches of the arteries running along by the side of those of the veins, two and two, to the general rendezvous assigned them by the Creator. The superior branches go up to the head, where they line the skull within and without. The collateral in like manner line the chest externally and internally. Hence they proceed each with its companion to the right and left; some directly towards the arms, others in every direction towards the spine. Lastly the inferior or descending branches wind along the membrane of the stomach, the intestines and all the other viscera, without forgetting either their common case, or the girth of the hips, or the two large columns, the tops of which are articulated with them to support the machine upon its pedestals; so that there is no part of the body, great or small, internal or at the extremities, neither nerves, tendons, muscles, ligaments, nor cartilages, but what contains some vein, fitting into an artery to receive from the latter the blood which, after an entire circulation, it is the office of the former to convey back to the heart.

Such is the course of our two great rivers (the aorta and vena cava), a course so frequently attended with apparent deviations, circuits, turnings, windings, and perpetual subdivisions into such a prodigious number of tubes, so delicate that their threads escape the naked eye, and can scarcely be perceived even with the microscope.

*Richard.* Papa, I see one of those red threads in the white of your eye.

*Mr. Vermont.* You must thence conclude that these minute blood-vessels are indefinitely ramified. These red threads run through every part of the body, and the blood circulates in them with very great velocity.

*Richard.* I am astonished at that, for the blood is pretty thick; and besides, if it were perfectly liquid, how could it run with such great velocity in a labyrinth intersected by so many channels?

*Mr. Vermont.* The author of Nature has made a provision for this purpose. He has given such force to the fibres of the heart, that their contraction is sufficient to propel the blood with a velocity truly astonishing; and as that part of the heart which is called the right ventricle has only to impel the blood through the lungs, it is observed that the muscles of that portion are not by far so strong as those of the right ventricle, which has to propel the blood to every part of the body*. I should like, my dears, to make you sensible, by means of comparisons suited to your capacities, of the possibility of the existence of such a force in the heart: but I am afraid of profaning so grand a subject by trivial comparisons.

*Richard.* O no, papa, don't be afraid. Consider that you are speaking only to children.

*Mr. Vermont.* Well then, if you have

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* Each ventricle, we are told by Dr. Keil, in his Anatomy, will at least contain an ounce of blood. The heart contracts four thousand times in one hour, from which it follows, that there pass through the heart every hour, four thousand ounces or three hundred and fifty pounds of blood. Now the whole mass of blood is said to be about twenty-five pounds, so that a quantity equal to the whole mass of blood passes through the heart fourteen times in one hour, which is about once every four minutes.

any doubt that the contraction of the heart possesses force sufficient to produce the circulation of the blood, take a cherry-stone.

*Richard.* A cherry-stone!

*Mr. Vermont.* Yes, my dear! press it between your thumb and fore-finger, and observe the velocity with which it will be projected.

*Richard.* O yes, I have often tried that experiment. The stone flies like lightning.

*Mr. Vermont.* Or take a handful of moist clay, squeeze it all of a sudden as the heart compresses the blood, and what will be the consequence?

*Richard.* The clay will quickly escape through the apertures between the fingers.

*Mr. Vermont.* As there are five fingers, the clay will issue through four apertures, but if there were only one, the velocity with which it would be expelled would be increased a hundredfold. You need but apply this to the velocity of the blood is suing from the heart, and you will see that its force must be very considerable.

*Richard.* Then the heart, the arteries and the veins are continually at work*.

*Mr. Vermont.* Yes, my dear, and that in whatever situation a person may be; whether standing upright, sitting, lying, bending, or even standing on his head, a posture which appears so contrary to the circulation of the blood.

*Richard.* The more we reflect on all this, papa, the more we must admire it.

*Mr. Vermont.* Indeed, my dear, the

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* "An anatomist who understood the structure of the heart, might say before-hand that it would play; but he would expect I think from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement, or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having at every stroke a great resistance to overcome; and shall continue this action for this length of time without disorder or weariness." *(Paley's Natural Theology).*

changes which the blood undergoes in its course, demand the highest admiration. The blood in the human body assumes a thousand different forms. 'Tis impossible to conceive how it can comprehend in its substance a sufficient number of different juices to nourish at one and the same time the flesh which is so soft, the nerves which are so solid, the cartilages which are so firm, the muscles and the tendons which are so strong, and the bones which are so hard.

*Alfred.* Papa, what is meant by muscles and tendons?

*Mr. Vermont.* The muscles are the fleshy parts, by means of which the motions of the body are performed. 'Tis these that constitute the flesh of animals. The tendons are prolongations of the muscles formed by white and very close fibres or threads*.

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* Keil has reckoned up in the human body four hundred and forty-six muscles dissectible and describable, and has assigned an use to every one of the number. Dr. Nieuwentyt, in the Leipsic Transactions, reckons up

*Richard.* And the nerves, where are they situated? What form have they, and what is their use?

a hundred muscles that are employed every time we breathe, without our consciousness of what a work is thereby performed. How many things must go right for us to be an hour at ease; and how grievous an inconveniency may arise from the defect or disorder of a very small instrument, for instance, of a single pair out of the four hundred and forty-six muscles! "With much compassion," says the author last mentioned, "as well as astonishment at the goodness of our loving Creator, have I considered the sad state of a certain gentleman, who, as to the rest, was in pretty good health, but only wanted the use of those two little muscles that serve to lift up the eyelids, and so had almost lost the use of his sight, being forcéd as long as this defect lasted, to shove up his eyelids every moment with his hands!"

The action and utility of the muscles shall be illustrated by an extract from Paley's Natural Theology.

"A muscle acts only by contraction. A finger is not bent or straightened without the contraction of two muscles taking place. It is evident, therefore, that the animal functions require that particular disposition of the muscles which we describe by the name of antagonist muscles; and they are accordingly so disposed. Every muscle is provided with an adversary. They act like two sawyers in a pit, by an opposite pull; and

*Mr. Vermont.* The nerves, my dear, are whitish cords issuing from the brain

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nothing surely can more strongly indicate design and attention to an end, than their being thus stationed, than this collocation. The nature of the muscular fibre being what it is, the purposes of the animal could be answered by no-other. And not only the capacity for motion, but the aspect and symmetry of the body is preserved by the muscles being marshalled according to this order. The mouth, for example, is held in the middle of the face, and its angles kept in a state of exact correspondence by two muscles drawing against and balancing each other.

" Of muscular actions, even of those which are well understood, some of the most curious are incapable of popular explanation; at least without the aid of plates and figures. This is in a great measure the case with a very familiar, but at the same time, a very complicated motion, that of the lower jaw, and with the muscular structure by which it is produced. One of the muscles concerned may, however, be described in such a manner as to be, I think, sufficiently comprehended for our present purpose. The problem is to pull the lower jaw *down*. The obvious method should seem to be, to place a straight muscle, that is, to fix a string from the chin to the breast, the contraction of which would open the mouth, and produce the contraction required at once. But it is evident that the form and liberty of the neck forbid a muscle being laid in such a position, and that, and spinal marrow, and extending over every part of the body. Their thickness is

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consistently with the preservation of this form, the motion which we want must be effected by some muscular mechanism disposed further back in the jaw. The mechanism adopted is as follows:—A certain muscle called the *digastric*, rises on the side of the face, considerably *above* the insertion of the lower jaw, and comes down, being converted in its progress into a round tendon. Now, it is manifest that the tendon, whilst it pursues a direction *descending* towards the jaw, must, by its contraction, pull the jaw up instead of down. What then was to be done? The descending tendon when it is got low enough, is passed through a loop or ring, or pulley, in the os hyoides, and then made to ascend, and having thus changed its line of direction, is inserted into the inner part of the chin; by which device, viz. the turn at the loop, the action of the muscle (which in all muscles is contraction), that before would have pulled the jaw up, now as necessarily draws it down. 'The mouth,' saith Heister, 'is opened by means of this trochlea in a wonderful and elegant manner.'

"The precision and celerity of muscular motion may be particularly observed in the execution of many species of instrumental music, in which the changes produced by the hand of the musician are exceedingly rapid. Or let a person only observe his own hand while he is writing; the number of muscles which are brought to bear inconsiderable, and like the blood vessels, they are subdivided into branches and twigs, which terminate in threads; and these latter are in general again divided into fibres of extreme tenuity.

*Richard.* What are the nerves composed of?

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upon the pen; how the joint and adjusted operation of several tendons is concerned in every stroke, yet that five hundred such strokes are drawn in a minute. Not a letter can be turned without more than one, or two, or three tendinous contractions, definite both as to the choice of the tendon, and as to the space through which the contraction moves; yet how currently does the work proceed, and when we look at it, how faithful have the muscles been to their duty, how true to the order which endeavour or habit hath inculcated!

"Bishop Wilkins hath observed from Galen, that there are at least ten several qualifications to be attended to in each particular muscle: viz. its proper figure; its just magnitude; its fulcrum; its point of action, supposing the figure to be fixed; its collocation with respect to its two ends, the upper and the lower; the place, the position of the whole muscle; the introduction into it of nerves, arteries, veins. How are things including so many adjustments to be made; or when made, how are they to be put together without intelligence!"

*Mr. Vermont.* Of a great number of threads, which are so many prolongations of the substance of the brain. They are extremely small *, yet each of them examined with a magnifier or microscope, appears composed of others of the same description; and it is probable that the latter are also bundles of fibres still more minute. It is very difficult to determine in what manner the nerves perform their office, because we are totally ignorant in regard to the elementary fibres of which they are composed. All we know is, that they are the real organs of motion and feeling. If the nerve which runs through a muscle were tightly tied just above the place where it enters the latter, in vain might we try to set the muscle in motion.

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* To assist the reader in forming some idea of the extreme minuteness of the nerves, it may be sufficient to mention that each fibre in the retina of the eye, or the expanded optic nerve, does not exceed in diameter the thirty-two thousand four hundredth part of a hair. The nerves are uniformly distributed, even to the smallest fibre; and yet were all those in the human body conjoined, they would not make a cord of the diameter of an inch.

*Richard.* I have not forgotten the important part performed by the nerves in the organs of sight, hearing, smell, taste, and feeling.

*Mr. Vermont.* If we go back to the origin of the word *nerve*, we shall find that it has not been given at random to these small white cords, which are the principle of motion and feeling in the human body. Nerve comes from the Latin word *nervus*, which is a compound. The first part is derived from *neo, nere*, which signifies *to spin;* and its termination *vus*, by an ellipsis very common in Latin, corresponds with *vivus, vivens*. A nerve therefore properly signifies a *living thread*[*].

*Richard.* O papa! I shall never forget this explanation; and henceforward I will study Latin with the more diligence, that I may the better understand my native language.

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[*] The Greek word νεῦρον has the same signification.

## *Explanation of Plate IV.*

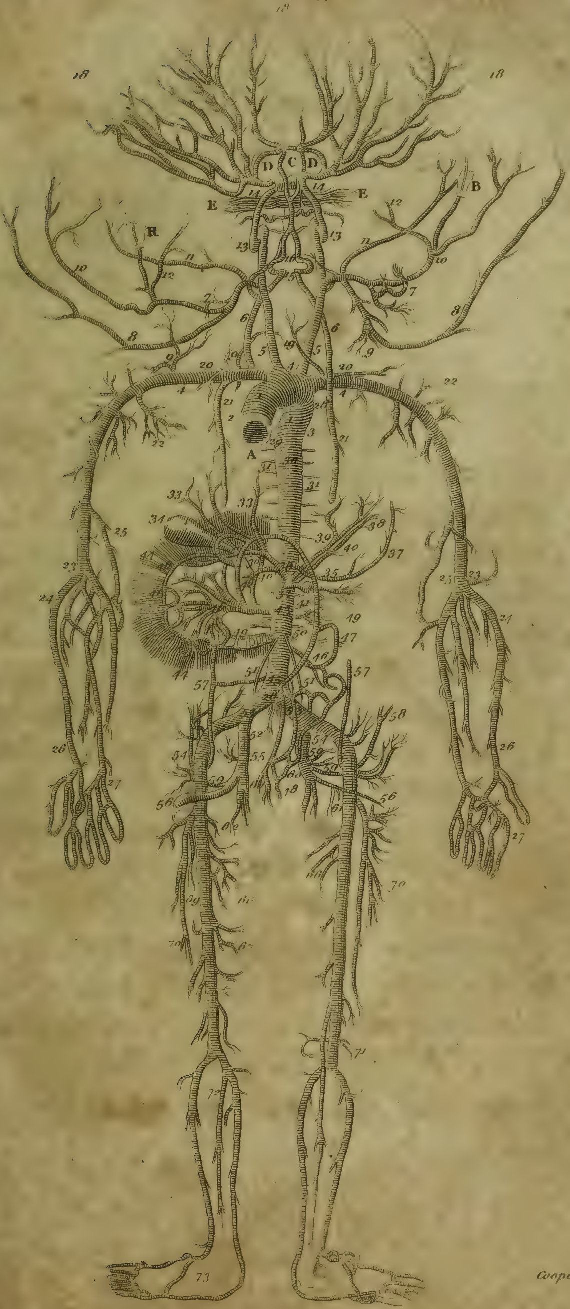
### *Distribution of the Arteries.*

The arteries are membranous tubes which convey the blood from the heart and pulsate; while the veins carry it back to the heart, and have no pulsation. This circumstance will enable the most unskilful to distinguish the nature of any blood vessel. The large trunks both of the arteries and veins are near the heart; at a distance from it they are divided into numerous small branches, in a manner very similar to that in which the trunk of a tree is lost in its branches and twigs.

Arteries are commonly said to diminish in size as they recede from the heart; but this is not really the case. As long as an artery continues undivided its diameter remains the same; and when it does divide,

# ANATOMY.

*Arteries.* *Plate IV.*



*Cooper sculp.*

*Published April 2, 1810, by R. Phillips, Bridge Street Blackfriars London.*

the area of the vessels formed by this division, is always greater than the area of the artery from which they are produced; so that the artery may in fact be said to be increased. This rule holds equally with respect to the division of the great trunks of arteries, and the subdivisions of their branches. The trunks also of veins are smaller than the sum of the smaller veins from which they are formed.

The branches of arteries are in general sent off at much more acute angles than those of the veins, by which the passage of the blood through the arteries is the less impeded.

The arteries have in general a corresponding vein placed near them. The trunks of the veins, and of almost all the arteries, are deeply seated, but the smaller veins are every where thickly distributed on the surface of the body, immediately below the skin. By this structure a passage is provided for the blood on the surface of the body, where the internal veins are so compressed by the action of muscles, as not easily to transmit their contents.

In the annexed engraving *(pl. IV.)* the arteries are represented freed from the muscular and fibrous parts, and are as follow:

1. Aorta ascendens.
A. Three semilunar valves.
2. Trunk of the coronary artery.
3. Aorta descendens.
4. Subclavian artery.
5. 5. Carotid arteries.
6. 6. Vertebral arteries.
7. 7. Arteries that go to the lower part of the face, tongue, &c.
8. 8. Temporal arteries.
10. 10. Trunks which go to the foramina narium, &c.
11. 11. Occipital arteries.
12. 12. Arteries which go to the fauces, &c.
B. B. A small portion of the basis of the skull.

13. 13. Contorsions of the carotid arteries, before they pass the brain.
C. The pituitary gland between the contorted trunks of
14. 14. The carotid arteries.
D. D. The opthalmic arteries.
15. Contorsions of the vertebrals.
16. The vertebral arteries, where they lie on the medulla oblongata.
18. 18. Ramifications of the arteries within the skull.
E. E. The arteries of the cerebellum.
19. 19. Arteries of the larynx, &c.
20. 20. Arteries which convey blood to the muscles of the neck and scapula.
21. 21. Mammary arteries.
22. 22. Arteries of the muscles of the os humeri, &c.
23. 24. Divisions of the arteries of the arm.
25. 25. A branch of an artery not found in all subjects.

26. External artery of the cubitus.
27. Arteries of the hands and fingers.
28. 28. Division of the aorta.
29. Bronchial artery.
31. Intercostal arteries.
32. Cœliac artery.
33. Hepatic arteries.
34. Arteria cystica, on the gall bladder.
35. Lower coronary artery of the stomach.
36. Pyloric artery.
37. Epiploic artery.
38. Ramifications of the coronary artery which embrace the bottom of the stomach.
39 The upper coronary artery of the stomach.
40 40 Phrenic arteries.
41. Splenic artery.
43. Upper mesenteric artery.
44. Superior branches of the mesenteric artery, freed from the small intestines.

45. Lower mesenteric artery.
40. 49. Emulgent arteries.
50. Arteriæ lumbares.
51. Spermatic arteries.
52. Arteria sacra.
53. 53. Common iliac arteries.
54. 54. Iliacus externus.
55. 55. Iliacus internus.
56. 56. Umbilical arteries.
57. 57. Epigastric arteries.
69. The crural artery.
70. Arteries which pass to the muscles of the thighs and tibiæ.
71. Part of the crural artery.
72. The three large trunks of the arteries of the leg.
73. Arteries of the foot.

## *Explanation of Plate V.*

### *Distribution of the Veins.*

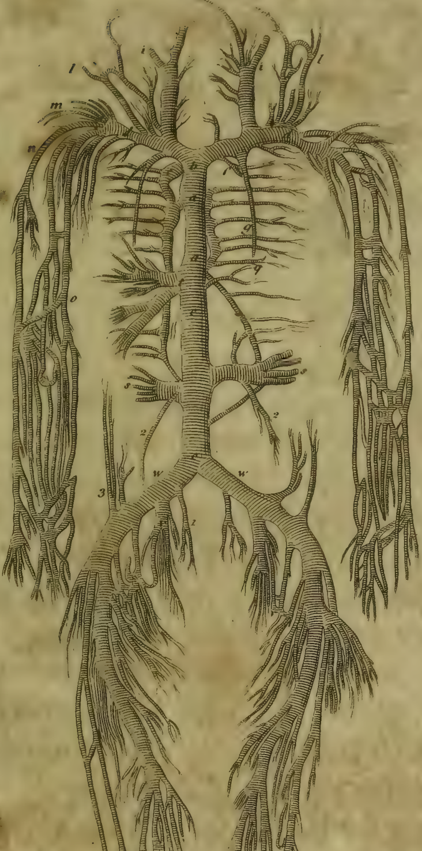
The veins may be divided into two classes, those which return the blood conveyed by the pulmonary artery, and those which return that of the aorta. Besides the blood which the lungs receive in common with the other parts of the body, they also receive all that is transmitted by the pulmonary artery. This, after being distributed through the substance of the lungs, is returned by veins that at length unite into four trunks, which are inserted into the posterior auricle of the heart.

The blood which is sent to the various parts of the body by the aorta, is ultimately received and returned by two large trunks, the vena cava superior and inferior, which enter the anterior auricle of the

# ANATOMY.

Plate V.

*Veins.*



*Cooper sculp.*

heart. These trunks, and the branches by which they are supplied, are as follow:

a. a. Vena cava.
b. Descending trunk of the cava.
c. c. Ascending trunk of the cava.
d. d. Subclavian veins.
e. Vena azygos.
f. Intercostal veins.
g. Mammary veins.
i. i. Internal jugulars.
l. l. External jugulars.
m. Right axillary vein.
n. Cephalic vein.
o. Basilic.
q. Phrenic.
s. s. Emulgents.
w. w. Iliac branches.
x. Internal iliacs.
1. Vena sacra.
2. Spermatic veins.
3. Epigastric.
4. Saphena.

# EIGHTH CONVERSATION.

## OF DIGESTION AND NUTRITION.

*Mr. Vermont.* Come, my dears, let us take a turn in the orchard. 'Tis very hot to-day, and we will refresh ourselves with some of the fruit.

*Richard.* With all my heart, papa. I am the more fond of fruit, because it quenches thirst at the same time that it appeases hunger.

*Eliza.* As you are so well acquainted with the interior of the body, papa, could you not tell me what is the cause of hunger and thirst? When I feel a violent longing for drink or food, whence does that longing proceed?

*Mr. Vermont.* It is easy to perceive the utility of those two sensations, but difficult to account for them. In the first place—

*Alfred.* I beg pardon, papa, for interrupting you. I hear the shrill sound of a bell.

*Eliza.* So do I. What is the meaning of this ringing? Where does it proceed from?

*Alfred.* If I am not mistaken, it must be some little bell in the windmill on yon hill.

*Eliza.* The sound, indeed, comes from that quarter; but a windmill is an out of the way place for a bell. What do you say to it, papa?

*Alfred.* The bell keeps on ringing.

*Eliza.* Now it has stopped. You smile, papa: but tell us what it is then. Was it not in the widmill that they were amusing themselves with ringing?

*Mr. Vermont.* The bell is certainly in the mill, but it was not rung for amusement.

*Alfred.* What rung it then?

*Mr. Vermont.* The wind.

*Eliza.* You are making game of us,

papa; the wind could not make it go at such a rate.

*Mr. Vermont.* You must know, however, that it is the wind which turns the sails of the mill.

*Eliza.* Certainly.

*Mr. Vermont.* These sails set in motion different wheels, the mechanism of which you are acquainted with, for you know in what manner wheat is converted into flour.

*Eliza.* You took the trouble to explain it to us, one day, papa.

*Mr. Vermont.* When there is no more wheat to be ground, a small spring worked by the sails of the mill, causes the bell which you heard to ring. Thus the mill itself gives the miller notice when he is wanted. As it is his interest not to suffer the mill to be idle, he immediately attends to this signal, and supplies the hopper with a fresh quantity of corn. The mill then begins to grind again, and as long as this supply lasts, the bell remains silent.

*Eliza.* You have made me fully sensible of the utility of this contrivance.

*Mr. Vermont.* Well, my dear, we have nearly the same kind of bell in our stomachs.

*Eliza.* A bell in our stomachs!

*Mr. Vermont.* Yes, something very like it: I mean the sense of hunger, which you just now enquired the cause of. We ought to be extremely thankful to the Author of Nature for having been pleased to add to the structure of the stomach a sensation which apprizes us of the necessity of a fresh supply of food.

*Alfred.* Oh! I understand you. Hunger performs the same office in our stomachs as the bell in the mill; it gives notice when there is nothing more to grind.

*Mr. Vermont.* Yes, the two cases are very nearly alike.

*Eliza.* You have already explained to us the mechanism of windmills, papa; can you now describe the mechanism of the stomach?

*Mr. Vermont.* That, my dear, is not so easy a task. We are no strangers to the track pursued by the aliments which we swallow: we know that they pass from the pharynx into the œsophagus or gullet, by which they are propelled into the stomach. We know that when they have once reached the latter, they remain there long enough to undergo a remarkable metamorphosis; but the manner in which it takes place has hitherto escaped the researches of philosophers*. We are ignorant, and,

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[*] Animal digestion must be considered a power and process completely *sui generis*, distinct from every other; at least from every chemical process that we are acquainted with. The varied experiments of the ingenious Spallanzani prove that it is not putrefaction; for the digesting fluid resists putrefaction most pertinaciously; nay, not only checks its further progress, but restores putrid substances. Neither is it a fermentative process for the solution begins at the surface, and proceeds towards the centre, contrary to the order in which fermentation acts. Nor is it the digestion of heat; for the [illegible] of a cod or sturgeon will dissolve the shells [illegible] lobsters, harder than the sides of the stomach which contains them.

It is, however, generally admitted, that the principal [illegible] of digestion is the gastric juice; a fluid which distils [illegible] certain glands, situated in the coats of the stomach, and mixes with the food as soon as it is [illegible]. The properties of this juice according to all appearance, shall ever remain so, of the preparation which the food

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are so remarkable, that we shall subjoin the following remarks on it by Paley:

"The gastric juice is of all menstrua the most active, the most universal. In the human stomach, consider what a variety of strange substances, and how widely different from one another, it reduces, in a few hours, to one uniform pulp, milk or mucilage. It seizes upon every thing, it dissolves the texture of almost every thing that comes in its way. The flesh of perhaps all animals, the seeds and fruits of the greatest number of plants, the roots, and stalks, and leaves of many, hard and tough as they are, yield to its powerful operation. The change wrought by it is different from any chemical solution which we can produce, or with which we are acquainted, because in this respect, as well as many others in our chemistry, particular menstrua act only on particular substances. Consider, moreover, that this fluid, stronger in its operation than a caustic alkali or mineral acid, than red precipitate or aqua fortis itself, is nevertheless as mild, and bland, and inoffensive to the touch or taste as saliva or gum-water, which it much resembles. Consider, I say, these several properties of the digestive organ, and of the juice with which it is supplied, or rather with which it is made to supply itself, and you will confess it to be entitled to a name which it has sometimes received, that of "the chemical wonder of animal nature."

receives in the stomach, in order to form the blood which circulates in and nourishes the body. This metamorphosis is a secret which the Author of Nature seems to have kept to himself, with a view to humble our pride, and to make us sensible of our dependence: perhaps he may likewise have had another motive for throwing an impenetrable veil over that operation.

*Alfred.* I should like to know what that could be, papa.

*Mr. Vermont.* That of relieving us from a very great anxiety.

*Eliza.* How so?

*Mr. Vermont.* Our ignorance on that head is not so much an imperfection, as an honourable discharge and a beneficial release. Man is thus dispensed from the humiliating and perplexing cares both of digestion, and of the numberless details of the various internal operations, which, had he been obliged to attend to the ordering and directing of them, would have furnished him with more than abundant employment. But what could have been the use of this exemption, unless to enable him to be continually engaged in external action, and to give himself up entirely to the exercise of his talents?

*Alfred.* Then we have as much reason to praise the wisdom of the Author of Nature, for what he has concealed as for what he has disclosed to us. For my part, I am very glad that he has kept us ignorant of what is going forward in our bodies. I should think that if our flesh were transparent like glass, and our eyes could observe the formation and circulation of the blood, the action of the muscles and of the nerves, in a word the movements of the whole machine, we should be in perpetual apprehension of putting it out of order*.

*Mr. Vermont.* And our apprehensions

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* "Durst we make a single movement," asks a French writer, "or stir a step from the place we were in, if we saw our blood circulating, the tendons pulling, the lungs blowing, the humors filtrating, and all the incomprehensible assemblage of fibres, tubes, pumps, valves, currents, pivots, which sustain an existence at once so frail and presumptuous?"

on that head would not be unfounded.—Man is naturally vain and self-sufficient; if he were acquainted with the nature and process of digestion, he would often presume to direct it and derange the whole.

*Eliza.* How often too would our eyes be shocked, if, according to Alfred's expression, our bodies were transparent!

*Alfred.* Eliza is right, papa. I have sometimes seen animals opened; and it is impossible to look without disgust at all that is extracted from their bodies.

*Mr. Vermont.* This disgust is natural: anatomists, however, conquer it, and to their researches we are indebted for most important discoveries.

*Richard.* You made use of a word just now, papa, which I should be glad to have an explanation of.

*Mr. Vermont.* What word was that?

*Richard.* You said that before the food reaches the stomach, it passes through the *œsophagus* or *gullet*.

*Mr. Vermont.* Yes, my dear, and to give you a perfect idea of the pipe which is thus denominated, it would be necessary to shew you some anatomical plates.

*Eliza*. But since we have none here, tell us something about it.

*Mr. Vermont*. Then listen to me attentively. At the root of the tongue begin two pipes placed one against the other, the œsophagus and the windpipe. The former receives drink and food, which it conveys to the stomach ; the other, which is the innermost, carries the air to the lungs, and conducts back that which is expelled from them.

*Richard*. I understand that. We breathe through the windpipe, and swallow with the œsophagus.

*Mr. Vermont*. Perfectly right. Now, whenever any other substance than air enters the windpipe, either from without, or internally by disengaging itself from the lungs, it produces violent motions in all the rings of the cartilage of which it is composed. It strives to get rid of this obnoxious substance by a convulsion which is called *coughing*. Woe betide us, if our food were to mistake the way, and insinuate itself into the windpipe, instead of passing through the œsophagus!

*Richard.* But, papa, as these two pipes are so close together, I should think such an accident might sometimes happen.

*Mr. Vermont.* Nature has provided against it, and as if in despite of the difficulty, it is above the very orifice of the windpipe that she has prepared the way which all our food must take, in order to pass through the œsophagus into the stomach.

*Richard.* What! does all that we swallow pass over the mouth of the windpipe, and yet nothing fall into it?

*Mr. Vermont.* This would at first view appear impossible, but by a contrivance worthy of an all-wise mechanic, there is at the top of the windpipe a small valve which opens and shuts, to allow a passage to the air, either when it enters by inspiration, or is expelled by expiration, but which closes in the most accurate manner the mouth of the pipe whenever the smallest portion of solid or liquid descends to the œsophagus. The great beauty of this precaution consists in this, that the most diminutive portion of food presses in its descent over the nerves of the root of the tongue, the action of which is always followed by the closing of the valve upon the windpipe, before the victuals or drink reach so far*.

*Richard.* What appears wonderful to me is, that this valve is not worn by the almost continual friction of the food.

*Mr. Vermont.* The works of Nature,

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* "We may remark," says Paley, "the almost complete success of this expedient, viz. how seldom it fails of its purpose, compared with the number of instances in which it fulfils it. Reflect how frequently we swallow, how constantly we breathe! In a city feast, for example, what deglutition, what anhelation! Yet does this little cartilage, the epiglottis, so effectually interpose its office, so securely guard the entrance of the windpipe, that, whilst morsel after morsel, draught after draught, are coursing one another over it, an accident of a crumb or a drop slipping into this passage (which nevertheless must be opened for the breath every second of time) excites in the whole company not only alarm by its danger, but surprise by its novelty. Not two guests are choked in a century."

my dear, are more durable, and a thousand times more admirable, than the productions of men. The prodigies of the human body are as numerous as its organs, that is to say, innumerable. Anatomy observes them as closely as it can, assigns names to them, is acquainted with the action of the most exposed, disputes respecting the use of the others, and acknowledges that the structure of them all, when we attempt to explore it, is an abyss which neither sight nor reason is capable of fathoming.

*Richard.* I should think, papa, that in time the food would injure the pipe which conveys it to the stomach, for it appears extremely narrow.

*Mr. Vermont.* Nature has likewise provided against that accident, which would have been a serious one; and the precautions which she has thought fit to take on this point were the more necessary, as the œsophagus is not destined merely to afford a free passage to food, but itself accomplishes their introduction into the stomach by the motion of its muscles.

*Richard.* I don't perfectly comprehend that.

*Eliza.* Nor I.

*Mr. Vermont.* It will not be difficult for me to make you understand it. Let us sit down here on the grass.

*Alfred.* Stop, sister; let us change places: you will sit better here; the grass is thicker and softer.

*Eliza.* No, I am very comfortable; let us listen to papa.

*Mr. Vermont.* When you swallow any thing, my dears, do you suppose that it drops down into your stomach by the force of gravitation, like a stone which you throw into a well? When you drink a glass of water, do you imagine that your stomach receives it as a bottle receives the liquor which is poured into it through a funnel?

*Alfred.* Yes, papa. Our food descends when we eat, because it finds a hollow underneath it.

*Mr. Vermont.* Do me the favor to lie down upon your back, and eat this pear.

*Alfred.* O dear, papa! what! before you?

*Mr. Vermont.* Do as I bid you.

*Alfred.* But why?

*Eliza.* Lie down and eat your pear: then we shall see.

*Alfred (Lies down).* Is that right? I see all the sky.

*Mr. Vermont.* Is the pear good?

*Alfred.* Excellent.

*Mr. Vermont.* Does it find its way without difficulty into your stomach?

*Alfred.* O yes.

*Mr. Vermont.* You see then that food does not descend into it by the mere effect of gravitation. Were this the case, you could only eat standing, and even then your victuals would very often be obstructed in the passage, which is narrow, as you just now remarked. Do you comprehend that?

*Alfred.* Yes, papa; I am now aware that, in order to reach the stomach, our food must be impelled into it, but I cannot conceive by what.

*Mr. Vermont.* It is by the contraction of the muscular fibres of the œsophagus. This pipe is composed of different muscles forming a series of circles or rings. As soon as any thing is introduced into it, these rings contract one after another at the upper part of the food, and by their alternate pressure oblige it to descend.

*Eliza.* I had no idea that so many springs were set in motion whenever I swallow a mouthful of victuals.

*Mr. Vermont.* There are a great many more, which I must pass over in silence, lest I should frighten you with terms which you would not understand. I shall therefore merely add one remark relative to the pipe which impels the aliments into the stomach. It appears that a final precaution was yet wanting to give still greater facility to their passage; this was that the canal should be continually wet; for as the food is often dry, it would have descended more slowly and with greater difficulty. To produce this effect, the œsophagus is furnished with a membrane full of blood-vessels, that is to say, arteries and veins, and beneath this there is a second called the glandular tunic, because it contains a great number of small glands, where is secreted from the arteries a liquor which lubricates the nervous membrane, as it is called, situated above the preceding, in order to adapt it to the purposes which I have just described. When these glands yield too small a quantity of this liquid, and the œsophagus is too dry, it is this that according to all appearance produces what we term thirst; which is a warning given us by nature to moisten those parts.

*Eliza.* Oh! I know now why we drink most during meals. The œsophagus being then at work, it is necessary to keep that passage moist.

*Richard.* You told us just now, papa, that nobody is acquainted with the preparations which the food receives in the stomach in order to its being rendered fit to form the blood which circulates in and nourishes the body. Do you mean to say that you don't know what becomes of the victuals when they are once impelled by the œsophagus into the stomach?

*Mr. Vermont.* No, my dear, their course is known; and we can even form conjectures respecting the process which they undergo in the stomach—for this they certainly undergo.

*Richard.* And what becomes of the food after it has entered the stomach?

*Mr. Vermont.* After the food, cut and ground by the teeth, mixed with the spittle, and moistened by the dissolving liquid, which distils from the glands of the œsophagus, has been again soaked in the stomach and reduced to the consistence of a pulp, it passes into the region of the intestines by a canal shaped like the worm of a still, and called the pylorus. The first of the intestines, which receives this pulp, is the duodenum, thus denominated, as anatomists tell us, because it is commonly about twelve inches in length. Be this as it may, there are in the membrane in which it is wrapped two small apertures for the admission of two other dissolving liquors. The liver, in the first place, pours forth its bile, to produce a new mixture; and the great gland, called the pancreas, sends thither at the same time a milder juice to temper the sharpness of the bile. The result of this is a second pulp, softer than the first, and even nearly liquid. Do you understand me?

*Richard.* Yes, papa: and what then?

*Mr. Vermont.* The food continues to be converted into chyle; and to accelerate this metamorphosis, the author of Nature has placed two distinct sorts of small vessels; the one, called *lacteals,* to extract from the intestines, by the filtres of their membranes, a liquor resembling milk; and the other, denominated lymphatics, to extract, by a similar process, a clear and colorless liquid like water. These fluids are discharged by their respective vessels into one common reservoir, where by their intermixture, they complete the formation of the chyle; that is to say, they give it the form of clarified milk; but it is still too thick or too imperfect to be immediately employed for the purpose of nutrition.

*Richard.* And where must the chyle go to, in order to receive its last preparation?

*Mr. Vermont.* To the reservoir of the blood. Nature has provided a canal to convey it directly thither, and has placed along it at irregular distances valves which open to afford a passage to the chyle and shut to prevent its return. This canal, which on account of its situation, is called the *thoracic duct*, joins the subclavian vein, to which it conveys its precious fluid, to be forwarded to the vena cava, which empties itself into the heart. You remember what I told you, one day, respecting the frequency of the pulsations of the heart?

*Richard.* Yes, papa, the heart beats sixty times in a minute, or almost one hundred thousand times a day.

*Mr. Vermont.* A slower movement would

have been insufficient to give the blood the preparation necessary to adapt it to the purposes of nutrition; while, comparatively speaking, the flame of a small lamp would be adequate to the formation of the chyle, a furnace is requisite to convert it into blood. Let us see how Nature performs this process.

The chyle, mixed with the blood in the vena cava, enters drop by drop into the right ventricle of the heart, and in this furnace a sudden fermentation, or if you please, a kind of ebullition takes place, and swells this new compound to a volume too great to be contained in it. It must therefore be expelled, and by what outlet? It cannot return into the vena cava, because the latter, after discharging it into the heart, closes its valves. It forces the doors of the artery of the lungs, which are formed to open inwards. It is upon its entrance into this canal that the chyle assumes the form of arterial blood, which differs considerably from that of the veins both in the redness of its color and its great fluidity. It soon takes a new form, which though nearly of the same kind, possesses much more of a living quality. The pulmonary vein, which receives this new blood from the artery of the same name, immediately conveys it to the left ventricle of the heart. What is the result of its exposure to this new furnace? A second fermentation, which, after completely purifying the blood, restores it in a perfect state to the grand artery, in order to its distribution over the whole body, that it may nourish all the parts of which it is composed*.

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* "Besides the subserviency of this structure collectively considered to a necessary and manifest purpose, we may remark," says Paley, "two or three separate particulars in it, which shew not only the contrivance but the perfection of it. We may remark first the length of the intestines, which in the human subject is six times that of the body. Simply for a passage, these voluminous bowels, this prolixity of gut, seems in no wise necessary; but in order to allow time and space for the successive extraction of the chyle, from the digested aliment, namely, that the chyle which escapes the lacteals of one part of the guts may be taken up by

*Richard.* But, papa, you said a little while ago that the process of digestion

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those of some other part, the length of the canal is of evident use and conduciveness. Secondly, we must also remark their peristaltic motion; which is made up of contractions following one another like waves upon the surface of a fluid, and not unlike what we observe in the body of an earth-worm crawling along the ground; and which is effected by the joint action of longitudinal and of spiral, or rather perhaps of a great number of separate semicircular fibres. This curious action pushes forward the grosser part of the aliment, at the same time that the more subtile parts, which we call chyle, are, by a series of gentle compressions, squeezed into the narrow orifices of the lacteal veins. Thirdly, it was necessary that these tubes, which we denominate lacteals, or their mouths at least, should be made as narrow as possible, in order to deny admission into the blood to any particle which is of size enough to make a lodgment afterwards in the small arteries, and thereby to obstruct the circulation: and it was also necessary that this extreme tenuity should be compensated by multitude; for a large quantity of chyle (in ordinary constitutions, not less it has been computed than two or three quarts in a day) is by some means or other to be passed through them. Accordingly we find the number of the lacteals exceeding all powers of computation, and their pipes so fine and slender, as not to cannot be explained; yet what you have just now told us—

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be visible, unless filled, to the naked eye; and their orifices which open into the intestines so small as not to be discernible even with the best microscope. Fourthly, the main pipe which carries the chyle from the reservoir to the blood, viz. the thoracic duct, being fixed in an almost upright position, and wanting that advantage of propulsion which the arteries possess, is furnished with a succession of valves to check the ascending fluid, when once it has passed them, from falling back. These valves look upward, so as to leave the ascent free, but to prevent the return of the chyle, if, for want of sufficient force to push it on, its weight should at any time cause it to descend. Fifthly, the chyle enters the blood in an odd place, but perhaps the most commodious place possible, viz. at a large vein in the neck, so situated with respect to the circulation, as speedily to bring the mixture to the heart. And this seems to be a circumstance of great moment; for had the chyle entered the blood at an artery, or at a distant vein, the fluid, composed of the old and the new materials, must have performed a considerable part of the circulation, before it received that churning in the lungs which is probably necessary for the intimate and perfect union of the old blood with the recent chyle. Who could have dreamt of a communication between the cavity of the intestines and the left great vein of the *neck?* Who

*Mr. Vermont.* Is a description of the fact, and not an explanation of the cause. We may to be sure affirm that digestion is effected by means of the different dissolving humors by which the food is moistened; but of the nature of those humors, and the mechanism of their action we are totally ignorant. Put into the hands of the most skilful anatomists and physiologists, liquids, herbs, pulse, bread, flesh of every kind, give them mortars, pestles, water, soap, fire, salt, vitriol, spirit of nitre, and as many other solvents and agents as they please; add to all these preparations, sieves, filtres, in a word, every possible mean of dissolving and filtering; still I maintain that they will never be able to make a single drop of chyle, and much less of blood. They may, it is true, produce a resemblance to milk, by mixing the

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could have suspected that this communication should be the medium through which all nourishment is derived to the body? or this the place, where, by a side inlet, the important junction is formed between the blood and the material which feeds it?

flour of almonds with water, and call it *milk of almonds;* but between that and chyle, real milk and blood, the difference is very great.

We have now, my dears, said enough on a subject, which, however attractive it may be to the philosophic eye, cannot have the same charms for you as other sciences better adapted to your age. It is sufficient that I have raised for you, a corner of the curtain which conceals from the ignorant the wonders of the human body. The time will come, when, if you desire it, you may acquire a more intimate knowledge of the subject Every part of the human body is equally worthy of admiration, and if, to use the expression of Galen, the author of Nature is never weary of producing wonders, man, on his part, ought never to be tired of studying them.

## *Explanation of Plates VI. and VII.*

### *Disposition of the Internal Parts of the Body.*

In order to render this introduction to a knowledge of the human body more complete, and consequently more acceptable to the inquisitive reader, a brief description of its internal parts, and their arrangement, shall be subjoined.

The body or trunk is divided by the diaphragm into two great partitions, the upper being denominated the thorax or chest, and the other the abdomen or lower belly. The diaphragm or midriff, (12, *pl. VI.)* is a broad strong muscle, which forms a kind of vault, attached in front to the sternum, on the sides to the ribs, and behind to the lumbar vertebræ. The vena cava and the œsophagus pass through it. The diaphragm not only serves to divide the two great cavities of the body, but from its muscular structure, it is one of the chief agents in respiration. When its fibres contract, its convex side, which is turned toward the thorax, becomes gradually flat, and by increasing the cavity of the breast, affords room for a complete dilatation of the lungs by means of the air which is drawn into them by inspiration. The fibres of the diaphragm then relax, and as it resumes its former state, the cavity of the thorax is diminished and the air driven out from the lungs, by a motion contrary to the former, called expiration. Besides this office, the acts of coughing, sneezing, speaking, laughing, gaping, sighing, and some others, could not be carried on without its assistance, and the gentle pressure which the viscera of the abdomen receive from its constant and regular motion cannot fail to assist in the performance of their several functions.

The thorax includes the vital organs, which are the heart and lungs, and likewise the œsophagus and the trachea or wind-pipe. The cavity of the thorax is every where lined by a membrane of a firm texture, called pleura. It is composed of two distinct portions or bags, which by being applied to each other laterally form the mediastinum. The latter divides the cavity into two parts, and is attached behind to the vertebræ of the back, and before to the sternum. By dividing the breast into two cavities the mediastinum obviates many inconveniences, to which we should otherwise be liable. It prevents the two lobes of the lungs from compressing each other when we lie on either side, and consequently contributes to the freedom of respiration. If the point of a sword penetrates between the ribs into the cavity of the thorax, the lungs on that side cease to perform their office; because the air, being admitted through the wound, prevents the dilatation of that lobe; while the other, separated from it by the mediastinum, remains unhurt and continues to perform its function as usual. The surface of the pleura, like that of all membranes which line cavities, is constantly bedewed with a serous moisture, which prevents adhesions of the viscera.

The two membranous bags of the pleura which form the mediastinum, recede from one another so as to afford a lodgment to a firm membranous sack, called the pericardium, in which the heart is securely lodged. It incloses also the great vessels which arise from the heart, and contains a quantity of transparent liquor by which its motions are facilitated.

The heart is placed almost transversely; the broad part being directed toward the right side, and the point or apex to the left, so as to strike the sixth rib when it beats. The substance of the heart is muscular. It includes two cavities or ventricles, separated from each other by a fleshy partition. At the base are also two muscular bags, denominated auricles, separated in the same manner as the ventricles, and like them called the anterior and posterior, or right and left. Each of them communicates with the ventricle placed next to it, *(5, 6, 7, pl. VI).* Between the auricles and ventricles, as also at the mouths of the great arteries, are placed valves which prevent the blood from passing in any other direction. Each auricle communicates with a large vein, and each ventricle with a large artery; the former receiving the blood and discharging it into the latter. The ventricle receives the blood from the auricle and drives it forcibly into the artery. By a repetition of these actions is performed the circulation of the blood, which has already been considered.

The lungs, *(10, 11, pl. VI),* whose use has also been described, fill the two sacks of the pleura, and occupy the greater part of the cavity of the breast. Their bases are broad and their summits form an obtuse cone. Their anterior surfaces, and those applied to the mediastinum are flat, that next the ribs is somewhat convex, and that behind round. The lower part of the left lung is excavated to make room for the heart. The color of the lungs is in infants reddish, in adults greyish, and in old age it approaches dark blue or black. They are connected above to the neck by means of the wind-pipe, and below by blood-vessels to the heart; being attached also to the sternum by the mediastinum before, and to the vertebræ by the pleura behind. The lungs are divided into two lobes, the right and left; the former consisting of three smaller lobes, the latter of two. These divisions gradually become more and more minute till at length they terminate in the cellular spaces, or vesicles, which compose the greater part of the substance of the lungs, and readily communicate with each other.

The œsophagus having been sufficiently described in another place, we proceed to the trachea, or wind-pipe, the canal through which the air passes into the lungs (1, *pl. VI)*. Its upper part, called the larynx, is composed of five cartilages, the uppermost of which is placed over the glottis or mouth of the larynx, and denominated epiglottis. This has already been spoken of as the valve which closes the passage to the lungs in the act of swallowing. All the cartilages of the larynx are united by means of very elastic ligamentous fibres, and are enabled, by the assistance of their respective muscles, to dilate or contract the passage, and to perform that variety of motion which seems to point out the larynx as the principal organ of the voice; for when the air passes out through a wound in the trachea it produces no sound. From the larynx the canal begins to take the name of trachea; descending thence as low as the third or fourth vertebra of the back, rather toward the right side of the spine, into the cavity of the thorax, where it divides into two great branches, which being afterwards subdivided, obtain the name of bronchia. Each of these bronchial tubes ramifies through the substance of that lobe of the lungs to which it is distributed by an infinite number of branches. The trachea is furnished with muscular fibres, some of which pass lengthwise through its whole extent, while others are carried round it in a circular direction, so that by the contraction or relaxation of these fibres it is enabled to shorten or lengthen itself, and likewise to dilate or contract its diameter. The cartilaginous rings of the trachea, by keeping it constantly open, afford a free passage to the air which we are obliged to be continually respiring. As, however, they do not form complete circles, but are imperfect behind, where the ring is completed by a soft but strong glandular and muscular membrane; this structure, by the contraction and dilatation of which it is susceptible, enables us to receive and expel the air in a greater or less quantity, and with more or less velocity, as may be required in singing or declamation. It also seems designed to assist in the descent of the food, by preventing the impediment to its passage down the œsophagus, situated immediately behind the wind-pipe, that might be expected if the cartilages of the latter were complete circles.

The abdomen or lower belly extends

from what is usually denominated the pit of the stomach to the lower part of the trunk. It is distinguished into three divisions or regions: the upper called the epigastric, the middle, or umbilical, and the third denominated the hypogastric. Each of these regions is subdivided into three others, two of which compose the sides, and the third the middle part. In the upper region the middle is called epigastrium, and its sides hypochondria. The middle part of the next is the umbilical region properly so called, and its two sides are the iliac regions. The middle part of the lower region retains the name of hypogastrium, and its sides are denominated inguina. The back part of the abdomen bears the name of lumbar region.

Strictly speaking, only those parts are said to be within the cavity of the abdomen, which are enveloped in a thin, transparent membrane called the peritoneum. These are the omentum or cawl, the stomach, the small and great intestines, the mesentery, the lacteal vessels, the pancreas, the spleen, and the liver. The organs not included in this covering, but placed behind it, are, the kidnies, the ureters, the receptacle of the chyle, the aorta, and the vena cava. The upper part only of the bladder is covered by a duplicature of this membrane.

The peritoneum is soft, yet strong, and capable of considerable extension. Its uses are, to keep the abdominal viscera in their places, and by the smooth and moist covering which it affords them, to prevent adhesions of one viscus to another. For this purpose it is admirably adapted, by being continually moistened with a serous fluid issuing from very minute pores.

The omentum, epiploon or cawl, is a membrane produced from the peritoneum, doubling upon itself at its lowest part, like an apron tucked up. The upper edge is tied to the bottom of the stomach, to the spleen, and to part of the duodenum. The reflected edge, after forming the doubling, comes up behind the front flap, and is tied to the colon and adjoining viscera. The uses of the omentum are not yet satisfactorily determined; but, containing a large quantity of fat, it has been suggested that the oily matter exuding from it, is designed to lubricate the intestines situated below.

The stomach, (16, *pl. VI.*) placed in the epigastrium, is a membranous and muscular bag, in form, when distended, not unlike a bagpipe, inclining rather more toward the left than the right side. It has two orifices, one of which to the left receives the end of the œsophagus, and is called the cardia, and the other to the right, denominated the pylorus, opens into the intestines. The stomach is composed of four tunics or coats, so intimately connected that it is difficult to distinguish them. The external is membranous, being derived from the peritoneum. The second is a muscular tunic composed of fleshy fibres, which are most numerous about the two orifices. The third is called the nervous coat, and within this is the villous or velvet-like coat, which composes the inside of the stomach. This last is constantly moistened by a fluid of the nature of the saliva, called the gastric juice. What has been said respecting the tunics of the stomach may be applied to the whole alimentary canal, for both the œsophagus and the intestines are, like this viscus, composed of four coats.

By the intestines is meant the whole of the alimentary tube beyond the stomach. They are divided into the small and the large. The small intestines comprehend the duodenum, the jejunum, and the ileum *(17, pl. VI.)*; the large are subdivided into the cœcum, the colon, and the rectum. *(13, pl. VII).*

Paley, in considering the manner in which the principal viscera are sustained in their places, makes the following observations illustrative of the structure of the intestines:—" It is pretty evident that a long narrow tube (in man about five times the length of the body) laid from side to side, in folds, upon one another, winding in oblique and circuitous directions, composed also of a soft and yielding substance must, without some extraordinary precaution for its safety, be continually displaced by the various, sudden, and abrupt motions of the body which contains it. I should expect that if not bruised or wounded by every fall, leap, or twist, it would be entangled, or involved with itself, or at least slipped and shaken out of the order in which it is disposed, and which order is necessary to be preserved for the carrying on of the important functions which it has to execute in the animal economy. Let us see, therefore, how a danger so serious and yet so natural to the length, narrowness, and tubular form of the part is provided against. The expedient is admirable, and it is this. The intestinal canal, throughout its whole process, is knit to the edge of a broad fat membrane, called the mesentery. It forms the margin of this mesentery, being stitched and fastened to it like the edging of a ruffle; being four times as long as the mesentery itself, it is what a sempstress would call puckered or gathered on to it. This is the nature of the connection of the gut with the mesentery, and being thus joined to, or rather made a part of the mesentery, it is folded and wrapped up together with it. Now the mesentery having a considerable dimension in breadth, being in its substance withal both thick and suety, is capable of a close and safe folding, in comparison of what the intestinal tube would admit of, if it had remained loose. The mesentery likewise not only keeps the intestinal canal in its proper place and position, under all the turns and windings of its course, but sustains the numberless small vessels, the arteries, the veins, the lymph-ducts, and above all, the lacteals, which lead from or to almost every point of its coats and cavity. This membrane, which appears to be the great support and security of the alimentary apparatus, is itself strongly tied to the first three vertebræ of the loins."

The pancreas, *(4, pl. VII.)* a glandular organ of a pale red color, and called in certain animals the sweet-bread, is situated in the epigastric region, behind the stomach. In form it resembles the tongue of a dog, with its pointed end stretched out towards the spleen, to which it is connected by blood-vessels, and the other extending towards the duodenum. It is eight or nine inches in length, and two or three in breadth. The pancreas is composed of an assemblage of small glands: these secrete a liquor, which in color, consistence, and other properties seems in no respect different from the saliva. Each of these glands sends out a little duct, which unites with others to form larger, and they all terminate at length in one common canal, called the pancreatic duct, which pours its contents into the duodenum, sometimes by the same orifice with the biliary duct, and sometimes by a distinct opening. This liquor, being of a mild and insipid nature, serves to dilute the alimentary pulp, and to incorporate it more easily with the bile.

The spleen (18, *pl. VI.* and 5, *pl. VII.*) is a soft, spongy viscus, of a color between deep red and blue, about five or six inches in length, and three in breadth, situated in the left hypochondrium between the stomach and the false ribs. Its figure is so irregular as not to admit of description; but it may be observed, that it is somewhat oblong, convex on the side which is applied to the ribs, and concave on that which is turned toward the stomach. The spleen is confined in its place by an adhesion to the peritoneum and diaphragm, and by a ligament to the omentum. It is extremely vascular, and when macerated seems wholly composed of numerous blood-vessels. It has no excretory duct, and it is remarkable, that, though an organ of such considerable size, its use is entirely unknown. Paley gives it as his opinion, that the spleen may be merely a stuffing, a soft cushion to fill up a vacancy or hollow, which, unless occupied, would leave the package loose and unsteady.

The liver, (13, *pl. VI.* and 1, *pl. VII.*) by far the largest gland in the body, is of a deep red color, and situated immediately beneath the diaphragm. It is divided into two portions or lobes, the larger placed in the right hypochondrium, and the smaller extending across the epigastric region towards the left. The upper surface of the liver is convex and smooth, corresponding with the concavity of the diaphragm. The lower surface is concave and uneven. The anterior and inferior margin is acute; the posterior and superior obtuse. "The liver," says Paley, "is fastened by two ligaments; the first, which is large and strong, comes from the covering of the diaphragm and penetrates the substance of the liver; the second is the umbilical vein, which after birth degenerates into a ligament. The first, which is the principal, fixes the liver in its situation, whilst the body holds an erect posture; the second prevents it from pressing upon the diaphragm when we lie down; and both together sling or suspend the liver when we lie upon our backs, so that it may not compress or obstruct the ascending vena cava, to which belongs the important office of returning the blood from the body to the heart."

The uses of the liver are to secrete and prepare the bile, which is conveyed to the duodenum by means of a channel called the hepatic duct.

It is however necessary for the purpose of digestion, that a portion of the bile should undergo a farther preparation. This it receives in the gall-bladder, (15, *pl. VI.* and 3, *pl. VII.*) a membranous receptacle, capable of containing two or three ounces. In shape it resembles a pear, and it is attached to the inferior part of the great lobe of the liver. The neck of the gall-bladder is continued in the form of a canal, denominated the cystic duct, which soon joins the hepatic duct mentioned above. They thus form the common bile duct, by which both the cystic bile, or that from the gall-bladder and the hepatic are discharged into the duodenum. The canal opens into the intestine in an oblique direction, first passing through the exterior tunic, and then piercing the other coats, after running a little way between each of them. This economy serves two useful purposes, to promote the discharge of bile, and to prevent its return. As there is no direct communication between the liver and the gall-bladder, in man, the bile must consequently pass to that reservoir through the cystic duct. The use of the gall-bladder seems to be to retain this fluid till, its more watery parts being removed, the remainder may become thicker, more pungent, and more acrid. It is so placed that it may be pressed upon the distended stomach, and its contents therefore discharged when they are most required to assist in the process of digestion. It is also emptied by the contraction and agitation of the viscera in vomiting. The bile contributes to blend the alimentary mass by dividing and attenuating it; corrects the too great disposition to acescency, and finally, by its acrimony, tends to excite that continual motion of the intestines, which is called peristaltic. The bile in the gall-bladder sometimes concretes into hard masses called gall-stones. As long as these remain in the gall-bladder, they occasion little or no inconvenience, but if any of considerable size pass into the ducts, they irritate and distend those vessels so as to produce exquisite pain. When these concretions are stopped in the common gall duct, they prevent the passage of the bile into the intestines. That fluid, then accumulating in the liver, is carried back into the circulating system, and occasions jaundice.

The kidneys *(6, pl. VII.)* are two organs of a pale red color, and firm consistence, in form resembling the beans which bear the same name; about six inches in length and four in breadth. They are lodged in a bed of fat, one on the right and the other on the left side of the spine, in the lumbar region, between the last false rib and the os ilium; the concave part of each being turned towards the aorta and vena cava ascendens. The office of the kidneys is to separate the urine from the blood. To this end they are formed of three different substances. The outer part chiefly consists of numerous convolutions of blood-vessels, and is called the cortical part. Beyond this is the vascular or tubular substance, and the inner part is papillary or membranous. It is in the first that the secretion is carried on. The fluid being there received from the minute extremities of the capillary arteries, is conveyed out of this cortical substance, by an infinite number of very small cylindrical canals which constitute the tubular part. These tubes, as they approach the inner substance of the kidney, gradually unite, and thus forming larger canals, at length terminate in ten or twelve little protuberances, called papillæ, each of which has several small orifices, through which the urine drops into a small reservoir. Hence it is conveyed from each kidney to the bladder by a membranous canal, called the ureter.

The ureters (11, *pl. VII.*) are about a span long, and in general about the size of a common goose quill. Both of them enter the bladder at the posterior part, near the neck, which is the most fixed point. Here we observe the same contrivance as in the passage of the common bile duct into the duodenum. The ureters run some distance between the different coats of which the bladder is composed, before they open into its cavity; which structure not only prevents the return of the fluid, but also the admission of air.

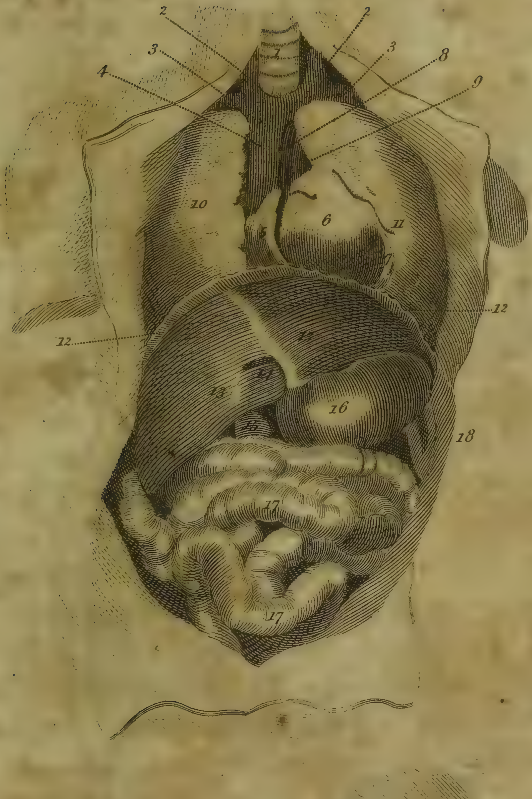
The bladder (14, *pl. VII.*) is a membranous sack of considerable size, and of an oblong roundish shape, situated at the anterior part of the pelvis. It is the reservoir of the excrementitious fluid which, as we have seen, is constantly filtering through the kidneys from the mass of blood. The bladder is connected behind to the rectum, and before to the ossa pubis. It is also attached by ligaments to the navel, and to the peritoneum, by which the upper and widest part of it is covered. Like most of the hollow intestines, it is composed of four coats.

## *References to Plate VI.*

1. The trachea.
2. The internal jugular vein.
3. The subclavian vein.
4. The vena cava descendens.
5. The right auricle of the heart.
6. The right ventricle; the pericardium being removed.
7. Part of the left ventricle
8. The aorta ascendens.
9. The pulmonary artery.
10. The right lobe of the lungs, part of which is cut off, to shew the great blood-vessels.
11. The left lobe of the lungs.

# ANATOMY.

Plate VI.



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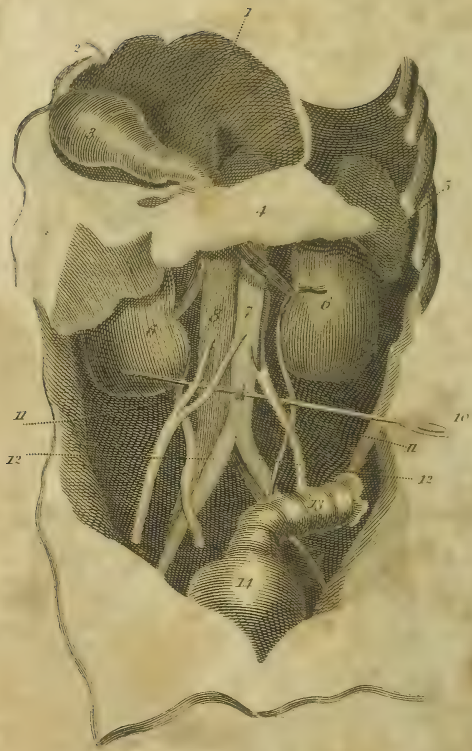
# ANATOMY.

Plate VII



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12. The diaphragm.
13. The liver.
14. The ligamentum rotundum.
15. The bottom of the gall-bladder projecting beyond the anterior edge of the left lobe of the liver.
16. The stomach, pressed by the liver towards the left side.
17. The small intestines.
18. The spleen.

### *References to Plate VII.*

1. The under side of the liver.
2. The ligamentum rotundum.
3. The gall-bladder.
4. The pancreas.
5. The spleen.
6. The kidneys.
7. The aorta descendens.
8. The vena cava ascendens.
9. The emulgent vein.
10. A probe under the spermatic vessels, and the arteria mesenteriaca inferior, and over the ureters.

11. The ureters.
12. The iliac vessels.
13. The intestinum rectum.
14. The urinary bladder.

THE END.

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